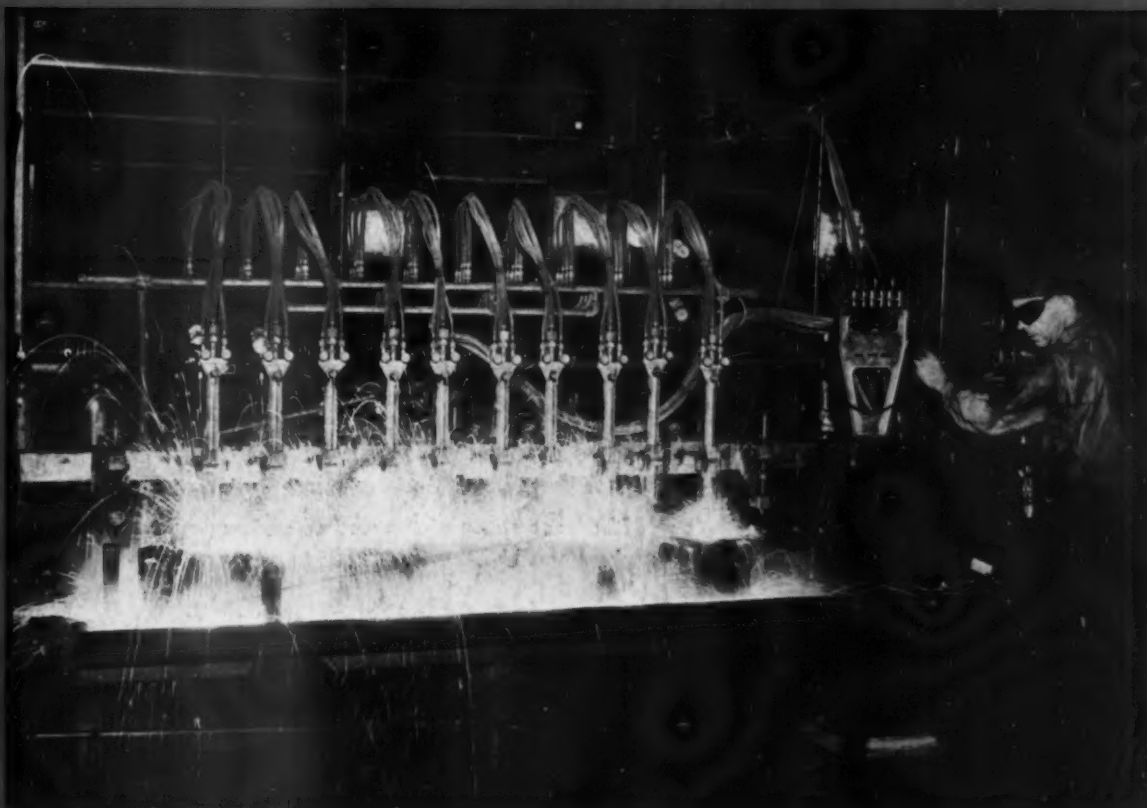
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

March, 1942



Multiple torches expedite the cutting of handholes in tubular header

Waterside Completes Topping Program ▶

Modern Turbine Developments ▶

Cleaning the Regenerative-Type Air Preheater ▶

COMBUSTION

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CONTENTS

FOR MARCH 1942

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Fuel Oil Outlook

Sinkings of tankers along the Atlantic Coast have taken toll of vast quantities of oil badly needed for industrial, domestic and marine use in the northeastern states. This, in the face of the present increased demands, has resulted in a heavy drain upon stocks at the refineries. Fuel oil in storage in the East is approximately two and a half million barrels below what it was a year ago, according to D. K. Davies, Deputy Petroleum Coordinator; and toward the end of February the depletion had amounted to nearly a million barrels in a week.

On the other hand, stocks in the Texas and Gulf Coast area are reported to be increasing because of the transportation situation. The railroads are endeavoring to fill the gap caused by tanker sinkings, but it requires many tank cars to equal the capacity of a tanker and the transportation cost is normally several times as great. However, when one takes into account the loss of ships and cargoes, together with war bonuses to crews and indemnities for the many lives lost, there is probably little difference in cost as between transportation by rail and by water under present conditions. It is only reasonable to expect this to be reflected in the price of the delivered product.

There is nothing in the present outlook that would indicate speedy control of the submarine menace, and if it should become necessary to convoy coastal tankers, the delays incident to the assembling and conduct of convoys would greatly restrict delivery of oil to the refineries.

Viewed from any angle, it would appear that the use of fuel oil in this section of the country is likely to be restricted, with those essential applications that cannot change to coal receiving first consideration. Fortunately, many stationary plants are equipped to burn either coal or oil as alternate fuels and many others can be changed over with minimum effort.

Engineering Guidance

The present demand by war industries for young men with technical training and some engineering background has placed a premium on those with such qualifications. This has been further intensified by the fact that the R.O.T.C. and the draft will draw heavily upon this year's graduates of engineering schools. While a number of short intensive courses are now being given, under Government sponsorship, to meet special requirements of the marine and aviation fields and to provide qualified technicians and inspectors in other lines of war production, these necessarily fall far short of the more comprehensive university course leading to an engineering or other degree.

Because of this situation, it is probable that many who are about to enter college will be led to take up engineering without a full understanding of what is involved or without giving adequate consideration to their aptitude for such work.

It is therefore most timely that the Engineers' Council for Professional Development has just issued a pamphlet entitled "Engineering as a Career" which broadly defines engineering, explains the scope of its several branches, tells what engineers are expected to do, outlines who should study engineering and gives helpful suggestions on the preparation for an engineering career. Engineering opportunities and earnings are also discussed.

All prospective engineering students, as well as their parents, teachers and advisers, would do well to study this pamphlet, to the end that fewer misdirected efforts may result and that only those who are likely to make a success of an engineering career will undertake such studies. By so doing much needless expense and disappointment will be avoided and the profession as a whole will be benefited.

Obviously, the present demand for engineers should not be taken as a criterian of that which may prevail in the post-war period. The general belief, however, is that the period of readjustment will call for the services of most of those engineers now engaged in war production.

Anti-Smoke Regulations vs. Coal Supply

Secretary Ickes, in his capacity as Director of Solid Fuels Coordination, has warned communities whose anti-smoke laws restrict consumers to certain kinds and sizes of coal that appropriate precautions should be taken immediately to assure against possible interruptions in their fuel supplies; otherwise it may be difficult to comply with such laws.

In many localities it has taken years of untiring effort on the part of civic bodies and engineering groups to attain present anti-smoke standards and it would be most unfortunate were they to be nullified by the exigencies of war conditions. While this may ultimately become necessary in some cases, as a temporary measure in the choice between no coal and smoky coal, it can probably be deferred or obviated altogether by the cooperation of consumers in stocking up on certain sizes and types of coal during periods of off-peak demand while transportation facilities are adequate.

However, despite previous warnings, the Office of Fuels Coordination reports that so far there has been little or no apparent effort at increasing stocks among industrial and domestic consumers and in some localities there has been an actual decrease in stocks on hand.

Complacency of consumers in this matter will not only react to the detriment of the community but to their own inconvenience, as well, should it become necessary for the Government to resort to allocation of coal to protect the fuel supply of war industries.

WATERSIDE COMPLETES

Part 1—Steam-Generation

By H. A. JOHNSON, Division Engineer,
Consolidated Edison Company of New York, Inc.

The topping of Waterside Station No. 1 of Consolidated Edison Company of New York, by the installation of high-pressure equipment in Waterside Station No. 2, involves a total of 236,000 kw high-pressure capacity in four turbine-generators, each served by two boilers. This development was carried on in two stages the first of which was fully described in COMBUSTION of September 1937. The present articles deal with the second or final stage, Part 1 covering the steam generating units and Part 2 the turbines and auxiliaries.

A REBUILDING program has been carried on during the past five years at the Waterside No. 2 Station of the Consolidated Edison Company of New York, Inc., located at 40th Street and the East River in New York City. This program was outlined in COMBUSTION of September 1937 and a description of the first half of the installation was described. This general plan has been carried out with but few exceptions. Originally, an additional low-pressure turbine-generator had been included but it was later decided to eliminate this unit because a firm capacity of 1,000,000 lb per hr of steam at 200 lb per sq in. had to be maintained for the New York Steam Corporation. This also made it necessary to revise the plans for feedwater treatment because of the resulting large amount of makeup.

While the first half of the Waterside improvement was being carried out, the City of New York decided to proceed with its East River Drive project involving the building of a superhighway through the Consolidated Edison Company property. Therefore, all waterfront facilities had to be moved out over the river on a new wharf. This involved the moving of all coal and ash handling equipment and the extension of the circulating-water tunnels, coal-conveying and ash-conveying equipment.

The turbines for the second stage of the program, which are designated as Nos. 6 and 7, require steam at 1250 lb per sq in. and 925 F, and each drives a generator rated at 65,000 kw, 3600 rpm, 13,800 volts, 60 cycles at 0.8 power factor.

Steam-Generating Equipment

Due to the fact that larger turbines had become available, the capacity of each of the four remaining boilers was increased from 500,000 lb per hr to 615,000 lb per hr. It was also specified that the boilers be capable of maintaining a capacity of 680,000 lb per hr for four hours. The increased size of these units required very careful fitting of equipment into the space available. Study of space conditions was aided considerably by making use of a wooden model, constructed in the drafting room, and having a scale of $^1/_2$ in. to the foot. Draftsmen, engineers, operators, equipment manufacturers and executives found the model to be of great value. Particular study was given to the general arrangement of all auxiliary apparatus in an attempt to consolidate the location of all attendance and to make communication as simple as possible.

Boilers—Unit No. 6

The two boilers comprising this unit, which serves one turbine, were furnished, delivered and erected by Combustion Engineering Company, Inc. These are of the three-drum bent-tube type with the effective heating surface of each distributed as follows:

Boiler,	10,815 sq ft
Superheater,	19,200 sq ft
Economizer,	20,100 sq ft
Air heaters (two),	108,200 sq ft
Furnace walls,	7,845 sq ft

The upper front drum is 54-in. diameter and $3^{23}/_{32}$ in. thick; the upper rear drum is 60-in. diameter and $4^1/_{16}$ in. thick; and the bottom drum is 36-in. diameter and $3^3/_{32}$ in. thick. All drums are fusion welded and the design pressure is 1475 lb per sq in.

The 60-in. drum is equipped with a steam washer and drier. A perforated feedwater pipe enters the drum and is enclosed in a feedwater trough over which is located a hooded steam baffle. Steam enters the hood, passes through perforations in the hood below the water line and emerges into the steam space. By this contact, the concentration of solids in the moisture in the steam is decreased. The steam leaves the drum through rod-type driers.

The furnace which has a gross volume of 29,000 cu ft is completely water cooled with 3-in. finned tubes. The walls are backed with $2^1/_2$-in. refractory tile, 4-in. rockwool blankets and a steel casing. The furnace bottom is arranged for continuous slag discharge, the bottom finned tubes being covered with 5 in. of chrome ore and backed up by 5 in. of firebrick and plastic refractory, together with a $2^1/_2$-in. course of insulating brick and a $^3/_{16}$-in. steel casing.

The Elesco pendant-type superheater is located between the first and second bank of boiler tubes and is de-

TOPPING PROGRAM

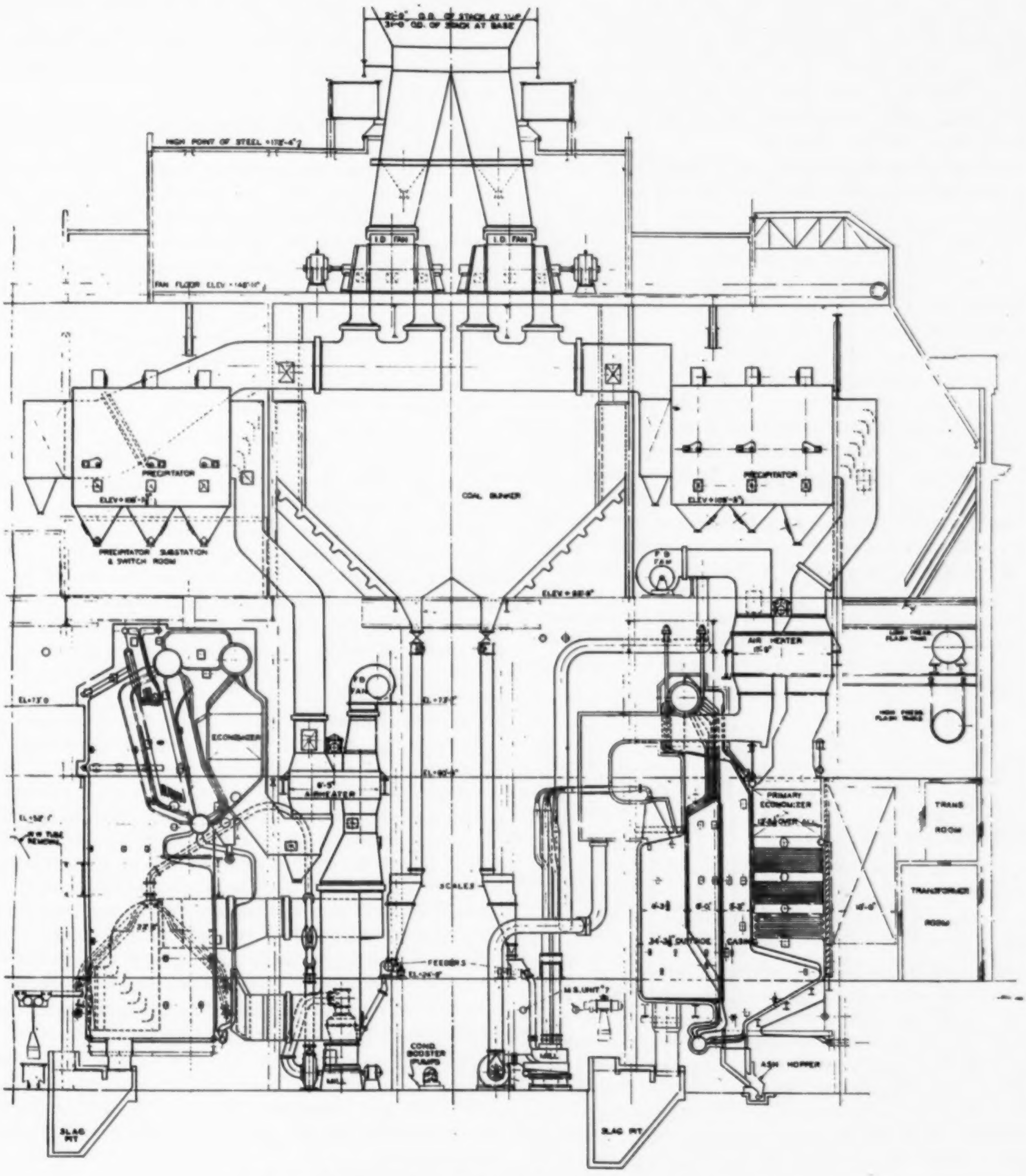

Fig. 1—Cross-section of boiler plant through units 6 and 7

signed to deliver steam at 925 F and 1340 lb per sq in. at the non-return valve outlet. Steam outlet temperature is controlled by the setting of a bypass damper between the first and second passes of the boiler. Hagan automatic temperature control is employed to maintain any desired steam temperature between 875 F and 925 F when operating at loads between 462,000 and 615,000 lb per hr. Chrome-molybdenum, titanium stabilized, low-carbon molybdenum and low-carbon tubing are used in each element. The outlet header is of carbon-molybdenum and is center connected to the non-return valve.

The economizers are of the Elesco horizontal, single-pass, fin-tube type with tubes 2 in. in diameter, spaced 5 in. vertically and 3 in. horizontally. Ten Diamond soot blowers serve each economizer.

Each unit is equipped with two Ljungstrom regenerative-type air preheaters, the elements of which are 48 in. high.

Tangential-type duplex burners are located in each of the four furnace corners and are fitted with Fahrite tips. The burner casing at each of the corners is equipped with an electrically ignited gas torch located between the top and bottom burner.

Two CE-Raymond bowl mills supply each boiler. The nominal capacity of each mill is 32,000 lb per hr, based on a coal having a grindability of 100 Hardgrove scale with 3 per cent moisture and grinding to a fineness of 80 per cent through 200 mesh. Raymond coal feeders driven through Sterling "Speed-Trol" variable-speed reducers are provided at each mill.

Two Diamond bi-color gage glasses are fitted to each boiler and have mirrors so located as to reflect the level image at the level regulating valves and the control board. All connections to the boilers have welding-ended valves. Each boiler is fitted with Consolidated safety valves and a Consolidated power-control valve. The non-return valves are of the Edward type with impactor handwheels.

Boilers—Unit No. 7

The two boilers for this unit were furnished, delivered and erected by Babcock & Wilcox Company and are of the open-pass type. Each has an effective heating surface distributed as follows:

Boiler (replaced by water walls)	
Superheater,	18,500 sq ft
Economizer,	22,600 sq ft
Air heaters,	128,000 sq ft
Water walls,	12,900 sq ft

The steam drum is 60-in. diameter and $4^1/_2$ in. thick, whereas the water drum is 30-in. diameter and $2^1/_2$ in. thick. Both are fusion welded and the design pressure is 1485 lb per sq in. The upper and lower drums are connected by means of two 25-in. I.D. downcomer pipes located at the ends of the drums. Seventy-five per cent of the tubes are partially studded, $7^1/_2$ per cent are fitted with blocks and the remainder are bare tubes. The 60-in. drum is fitted with cyclone separators and plate driers.

The continuous-loop type superheater is located in the last pass and is designed to deliver steam at 925 F at a pressure of 1340 lb per sq in. at the non-return valve outlet. Steam outlet temperature is controlled by means of setting dampers at the superheater and economizer outlets. Bailey automatic temperature control is employed. This is designed to maintain any desired steam temperature between 875 F and 925 F when operating at loads between 462,000 and 615,000 lb per hr. The superheater is arranged in two vertical sections of three horizontal banks each. In between the two vertical sections is an economizer section separated from the superheater by means of vertical baffles. The tube spacing in the superheater is the same as that given below for the economizer. Sections of economizer are also located over the superheater sections. Chrome-molybdenum, low-carbon molybdenum and low-carbon tubing is used in each element. The outlet header is of carbon-molybdenum and is center connected to the non-return valve which is located at the bottom of the boiler.

The economizers are of the B. & W. continuous-tube type. An inlet header is located at the top of the upper section, an upper intermediate header at the bottom of the upper section, and the second intermediate header at the bottom of the lower section; the outlet header being at the top of the lower section. Water flows downward in the upper section and upward in the bypass section. The upper section is 87 tubes wide, 25 tubes high and spaced horizontally on 4-in. centers. The bypass section is 21 tubes wide, 26 tubes high and spaced horizontally on 4-in. centers for the upper eighteen rows and on 8-in. centers for the lower eight rows. Eight Diamond soot blowers serve each economizer.

The studs in the partially studded portion of the water walls are resistance butt-welded to the tubes and are used as a support for the plastic chrome ore between the tubes and at the same time serve as extended surface into the chrome ore for both cooling and bonding purposes. The walls are backed by high-temperature insulating cement applied directly to the back of the tubes and pressed into place to fill the spaces between the tubes and a plane surface $3^1/_2$ in. from the center line of the $3^1/_4$-in. wall tubes. Rockwool blankets are cabled in place with $^3/_{16}$-in. steel cables fastened to eye-bolts welded to the outside of the tubes. A 10-gage steel casing encloses the insulation. Under the primary furnace and the first pass, the floor is arranged for continuous slag discharge. The furnace floor is covered with Bailey cast-iron blocks attached to the tubes with a heat-conducting bond between the blocks and the tubes. Over this construction is placed a varying thickness of chrome ore. Under the second pass there is a dry-ash hopper. The floor under the superheater is also fitted with cast-iron blocks and slopes to the dry-ash hopper. Steam jets are located in this floor for ash-removal purposes but have not had to be used. The wall is backed with insulating cement, rockwool blankets and steel casing.

Each unit is equipped with two Ljungstrom regenerative-type air preheaters having elements 60-in. high.

Six multiple vertical inter-tube type burners are used. These are arranged in one row in the roof of the primary furnace chamber. Each of these burners has an electrically ignited gas torch. The tips and nozzles are calorized.

Two B. & W. type "E" pulverizers are employed per boiler and are designed to operate as outlined under Boiler Unit No. 6. The coal feeders, located at the operating floor, are of the rotating-table type, the rate of feed being controlled by intermittent operation at full speed and half speed. Speed is determined by an automatic coal level control.

Each boiler is equipped with two Diamond bi-color gage glasses, fitted with mirrors so located as to reflect the level image at the level regulating valves and the control board. Consolidated safety valves and a Consolidated power-control valve are installed on each boiler. Powell hand-operated non-return valves are used.

Slag Handling

Both units, comprising four boilers in all, are arranged for continuous slag discharge. Attached to the floor tubes forming the edges of the openings is a stainless-steel cooling ring. This ring is externally connected between the booster pump discharge and suction headers, and directly under the cooling ring is a spray ring which operates continuously. Slag falling through this spray is broken into particles about the size of rice which fall by gravity into a water-filled slag pit, the bottom of which is sloped toward and beyond an edge of the boiler. Alongside the boiler and over this pit is an electric trolley hoist equipped with a de-watering clamshell bucket. The slag is hoisted from the pit, deposited into storage battery trucks and transported therein to slag and stoker ash bunkers located above the wharf. In the case of the boilers comprising No. 7 Unit, where dry ash is collected in hoppers below the third pass, the ashes are hydraulically sluiced intermittently into the above-mentioned slag pit and are handled in the hoist and cars.

Feedwater Treatment System

Makeup water is taken from the city water supply and passed through a Permutit "Zeo-Karb" feedwater treatment system having a capacity of 1,200,000 lb per hr. In this system, water passes through a main inlet valve which is fully opened or closed as required by the demand for makeup, as measured in a treated-water storage tank. The flow then splits through two proportioning valves which regulate the quantities of water delivered to the hydrogen and sodium units. The two streams then merge and pass through a degasifier where the major portion of carbon dioxide is removed. The makeup water is taken from the storage tank and led to the low-pressure turbine condensers where it is partially deaerated and mixed with the main low-pressure condensate and delivered by pumps to the high-pressure condensate system and surge tank. The demand for makeup is satisfied by controlling a valve in the treated-water makeup line to the condensers in accordance with changes of water level that occur from time to time in the surge tank.

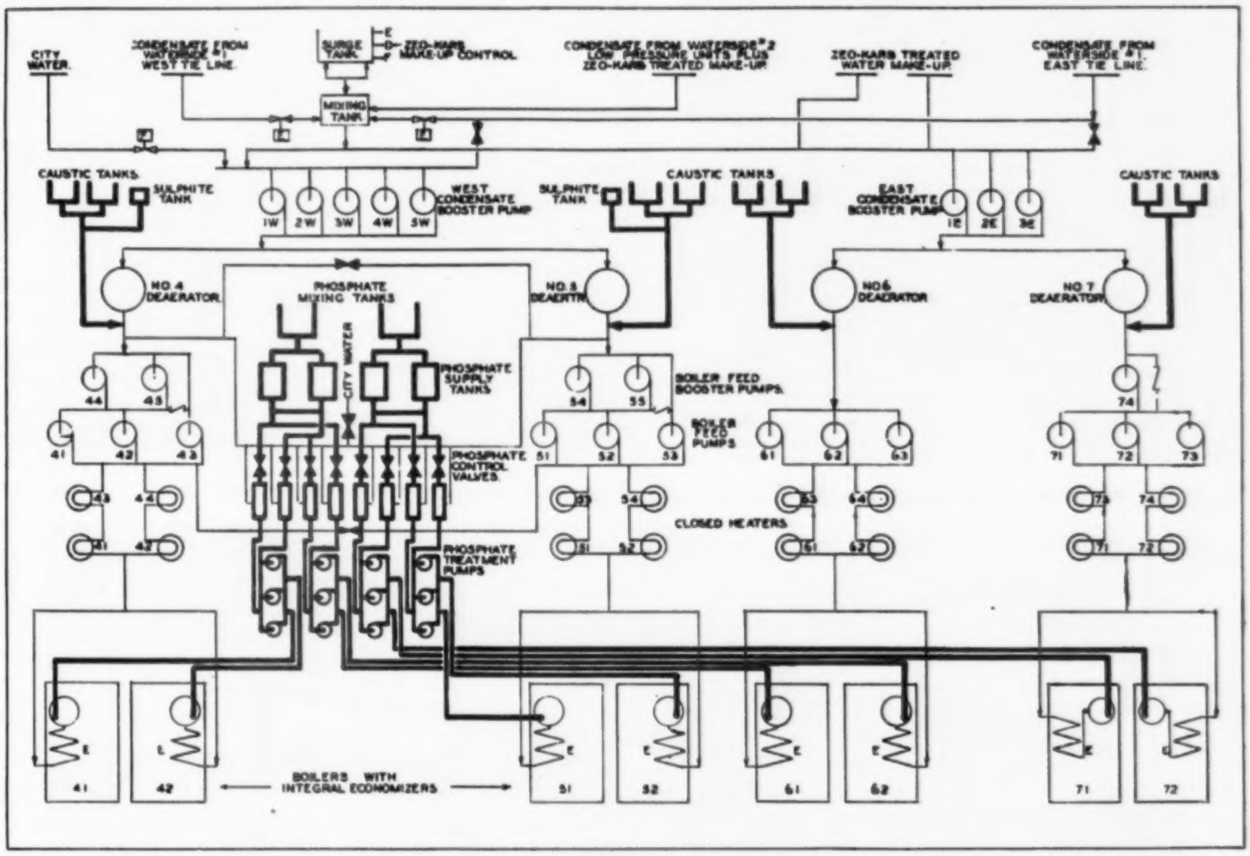

Fig. 2—Diagram of feedwater system

In addition to the Zeo-Karb system, proper proportions of treatment chemicals are maintained in the boiler water by feeding sodium hydroxide into the feedwater lines at the deaerator outlet, by pumping phosphate directly into the boiler drums and by the use of a continuous blowdown system which maintains the desired solids concentration in the boilers.

Forced- and Induced-Draft Fans

Two Sturtevant forced-draft fans serve each of the boilers. These are designed to deliver 100,000 cfm of air at 100 F, at a static head of 11.5 in. of water in the case of the No. 6 Unit and 15 in. of water in the case of the No. 7 Unit. The fans are vane-controlled and each pair

Installation Views at W

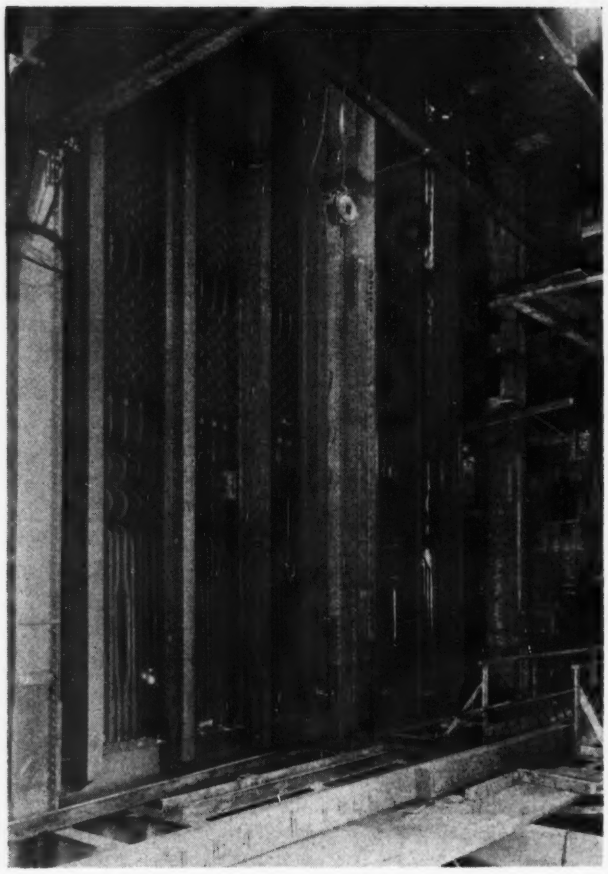

Fig. 3—Superheaters and economizers, No. 7 unit

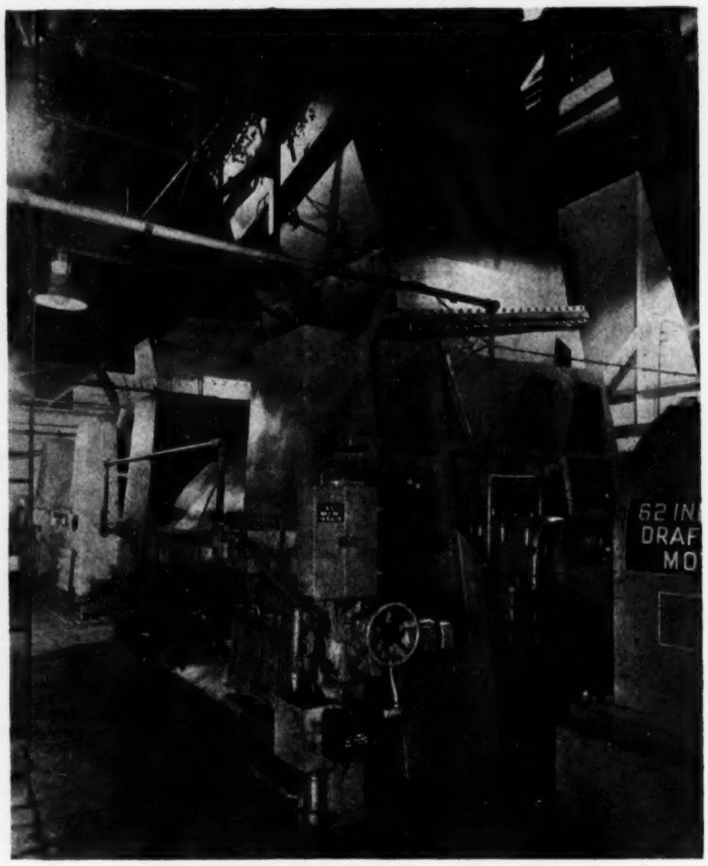

Fig. 4—Mechanical draft fans located directly under stack

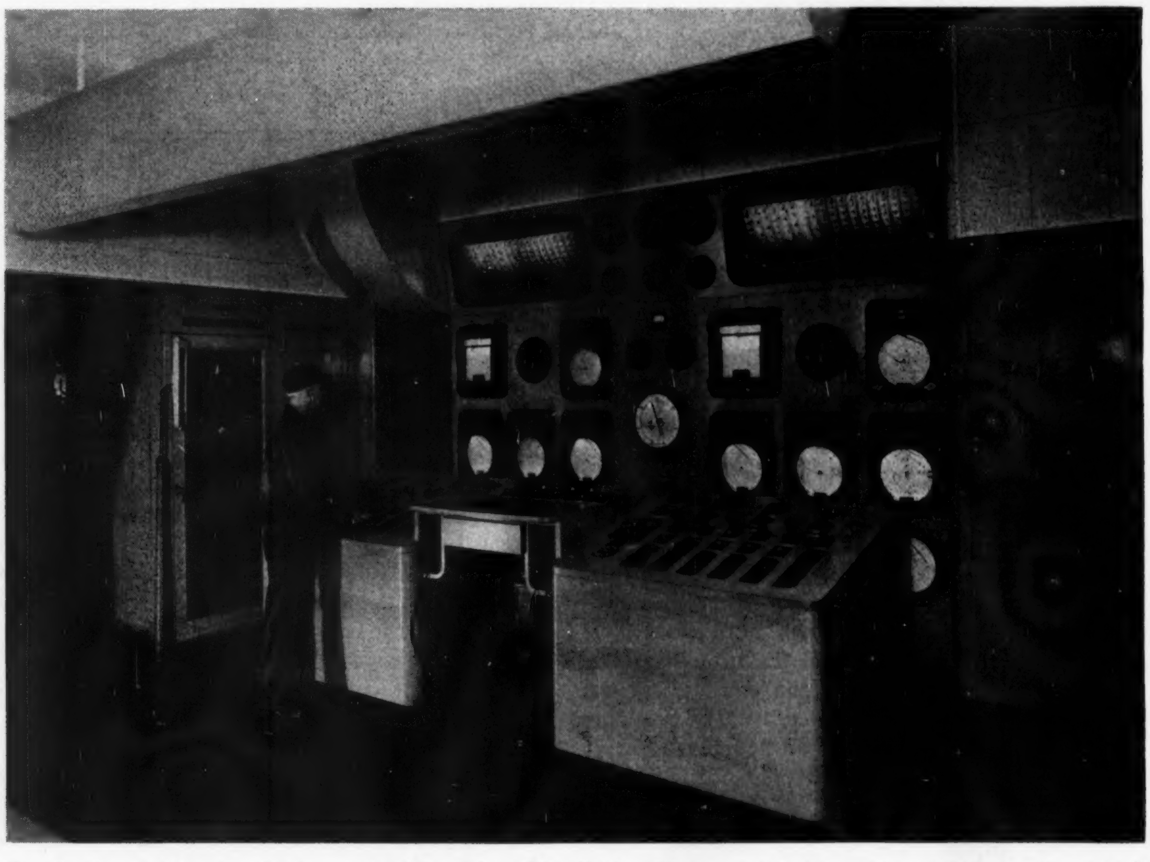

Fig. 5—One of the two boiler control boards. The Bailey Meters, at bottom of vertical panel, control feedwater and superheater temperature

at Waterside Station No 2

Fig. 6—View looking upward in furnace of C-E unit

Fig. 7—One of the mills for No. 7 unit

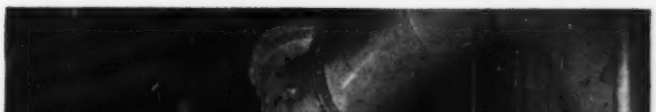

Fig. 8—One of the mills for No. 6 unit

is driven by a single induction motor at 1188 rpm. One Sturtevant induced-draft fan capable of delivering 300,000 cfm at 330 F and at a static head of 16 in. of water is provided for each boiler. They are vane-controlled and each is driven by an induction motor at 1188 rpm. These fans are located after the precipitators at the base of the stack.

Boiler Control Boards Embody Special Arrangement Features

Combustion control equipment was furnished by the General Regulator Corporation and is similar to that furnished for the first four boilers as described in September 1937 COMBUSTION. One radical change was made, however, in that the control boards have been arranged in an entirely different manner. It was thought advisable to bring together the control boards for the two units and to arrange the coal feeders, gage-glass system and feedwater regulating systems so as to be near at hand. The control boards for the first two units (four boilers) were of the conventional vertical type and were black in color, very congested and difficult to build. No satisfactory lighting system for such a board could be devised.

After a study of the disadvantages of such a design, together with a consideration of what might be an ideal board, the present design was evolved. All switches, push buttons and position indicators were installed on a benchboard inclined slightly from the horizontal toward the operator's position. All instruments and indicating lights were placed on a vertical board located about 3 ft beyond the benchboard. The upper portion of the vertical board is tipped toward the operator's position in order that no confusing reflections may exist on any surface.

A full-size model constructed of wall-board and light framing was built in order to study heights, angles, colors, reflections, location of instruments, etc. Catalog pictures of all apparatus faces were photographed and enlarged to full size in order to assist the designers and operators in picking the proper location. Many materials were considered for board faces and a gray linen design of Formica covering was finally selected. The Formica is mounted on seven-ply board about 1 in. thick. Under the Formica on the front sides, is located a paper-thin sheet of aluminum the purpose of which is to prevent damage from burns.

The benchboard is constructed with sliding doors for the entire length. The bottom of the interior of the benchboard is about 3 ft below the operating floor of the control room, and the rear of the vertical board is enclosed by a roller-type shutter door extending the entire length of the back. The ceiling over the entire control room is sound absorbing. A vertical panel encloses two ends of the room and the ceiling construction forms walls at the sides of the room to within 7 ft of the floor except where filled in by valve-control panels. If found desirable at a later date, these sides will be continued to the floor and will be provided with doors and openings for light beams emanating from all of the gage glasses. A small deck section is provided in the middle of each control board bench, one for Unit No. 6 and one for Unit No. 7. Columns within the room are fitted with closets, for Orsat apparatus, etc., and others for personal effects of operators, such as tea-pots, cups, toasters, etc. Fig. 5 is a view of one of these boards. The other is similar except for some different types of instruments being employed.

Raw coal is handled by two Maine Electric traveling coal towers and one fixed Mead-Morrison steam tower. The coal is crushed when required and transported by means of a newly designed belt system to the top of a structure opposite the middle of Waterside No. 1, thence to Waterside No. 1 and Waterside No. 2. Shaker screens and rag pickers are installed on the trippers of Waterside No. 2. Two Redler conveyors are located immediately below the bunker. These conveyors are operated only to the extent necessary to prevent bunker fires. Richardson automatic weigh scales are provided in the coal downtake to each mill, thus affording a ready record of the amount of coal that is handled by the individual mills.

Fly-Ash Recovery and Handling

Each of the No. 6 and No. 7 boilers is served by a Cottrell precipitator. These are of the steel-plate electrode type, two units wide and three sections long, along the gas travel. The steel-plate electrode precipitators were chosen because this type required less volume per cubic feet of gas treated than the concrete-plate type previously selected for Boilers 4 and 5. They are designed for 95 per cent efficiency when treating the gas from the boilers operating at 680,000 lb per hr. The dust is removed from the plate electrodes by a rapping mechanism and falls into hoppers from which it is removed by the pneumatic ash-disposal system.

The fly ash from the Cottrell precipitators, boiler hoppers and flues is transported by a United Conveyor Corp. pneumatic system controlled manually or automatically. Three complete vacuum producers, separators and bag filters are located in a structure on the wharf. One set is spare for either of the two systems which serve the entire boiler house. Each pair of separators and filters is mounted centrally between two circular bunkers. Four bunkers are provided, two for high-carbon and two for low-carbon ash. The pneumatic system is so interlocked that ash of low carbon content can be automatically separated into two of the bunkers and subsequently sold.

All of the coal bunkers are arranged to load dry ash to the land side in bulk or for subsequent installation of bagging machines. They are also arranged to be unloaded on the water side into bottom-dumping scows. Below each bunker is a mixer wherein enough water is mixed with the ash for dustless handling. From each mixer, the ash falls on a horizontal conveyor belt and is carried to the scow. Each conveyor is retractable and jointed so that the outboard end may be dipped downward into the barge. Conveyor movement is push-button controlled and is so interlocked that the conveyor holds a horizontal position during propulsion or retraction.

Part 2—Turbines and Auxiliaries at WATERSIDE

By H. KNECHT, Division Engineer,

Consolidated Edison Company of New York, Inc.

WITH the placing in operation recently of two 65,000-kw topping turbine-generators, together with the four additional high-pressure boilers at Waterside Station, the Consolidated Edison Company completed a program initiated in 1937. The original plan called for the installation of four 50,000-kw topping units, but due to changing conditions, two 53,000-kw and two 65,000-kw machines were finally installed. As shown in Fig. 10, the new installation follows very closely the general layout of the two preceding installations and the policy of omitting steam and boiler feed interconnections and reducing valve systems has been continued. Adoption of this policy has resulted in simpler high-pressure piping layouts and therefore lower installation costs. Since there is sufficient reserve capacity, constantly in operation, to take care of the dropping out of one 160,000-kw low-pressure machine, the loss of one of the topping units would not be serious. Availability factor experience of the high-pressure equipment averages between 81 and 89 per cent, further justifying the "unit" system.

Simultaneous installation of Units Nos. 6 and 7 permitted the design of common pumping systems for low-pressure salt-water cooling and condensate. This reduced the number of pumps from five to three units in each case. As a result of heat balance requirements, all of the auxiliaries are driven by constant-speed motors with the exception of the bleeder-turbine boiler feed pump drives for Unit No. 6, and other spare pump drives.

The steam distribution between the high-pressure and low-pressure systems is indicated on Fig. 11. By an examination of this diagram, it will be noted that the topping units supply sufficient low-pressure steam for all of the low-pressure turbines. The low-pressure boilers in Waterside Station No. 1 are therefore available to take care of demands of the N. Y. Steam Corporation up to approximately 1,000,000 lb per hr during peak electrical loads; and to provide low-pressure steam when one or more of the topping machines are out of service.

The steam conditions of the turbine-generators designated as No. 6 and No. 7 are 1250 lb per sq in., 925 F, and each machine consists of a high-pressure section and a low-pressure section on a common shaft, the latter being supplied by 200-lb steam from the high-pressure unit exhaust.

The operation of the feed-heating turbines for supplying steam to the intermediate, primary and deaerating heaters has proved entirely satisfactory. The original study considered the use of bleed steam for heating from

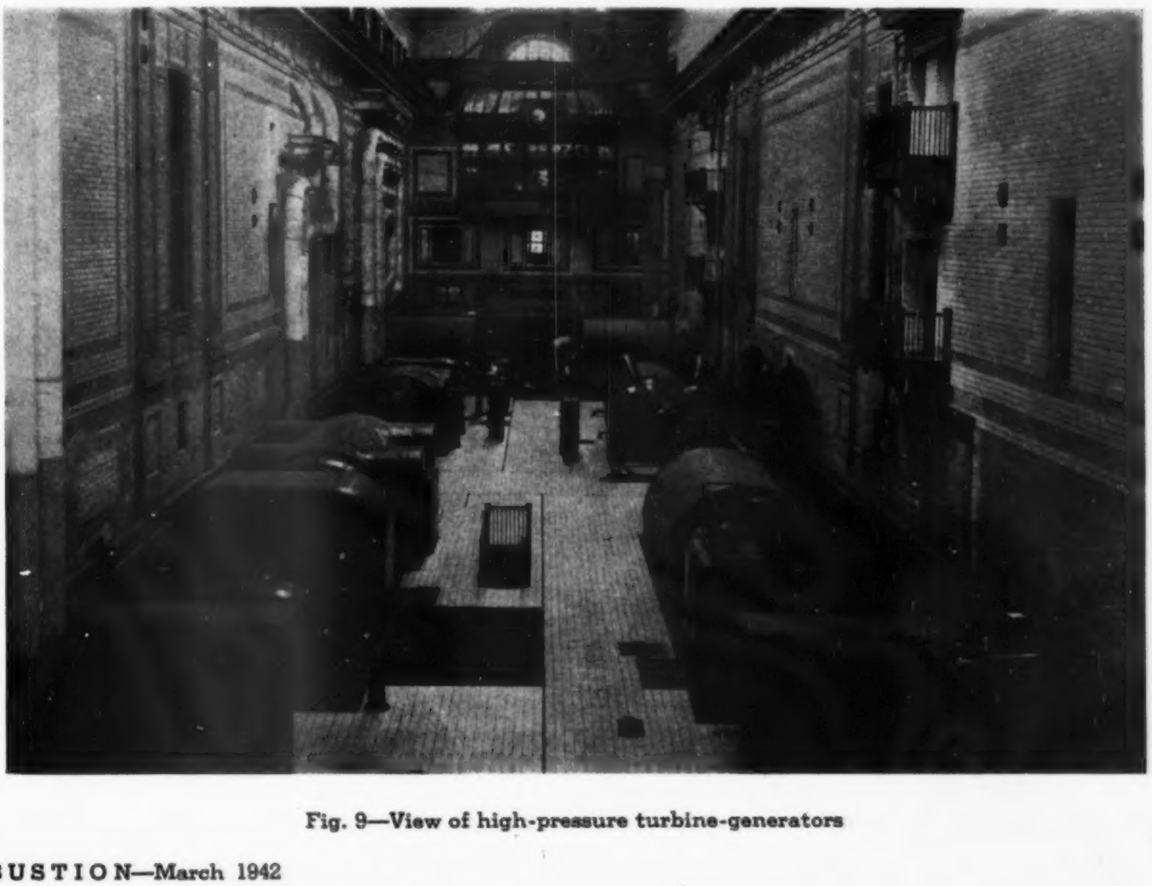

Fig. 9—View of high-pressure turbine-generators

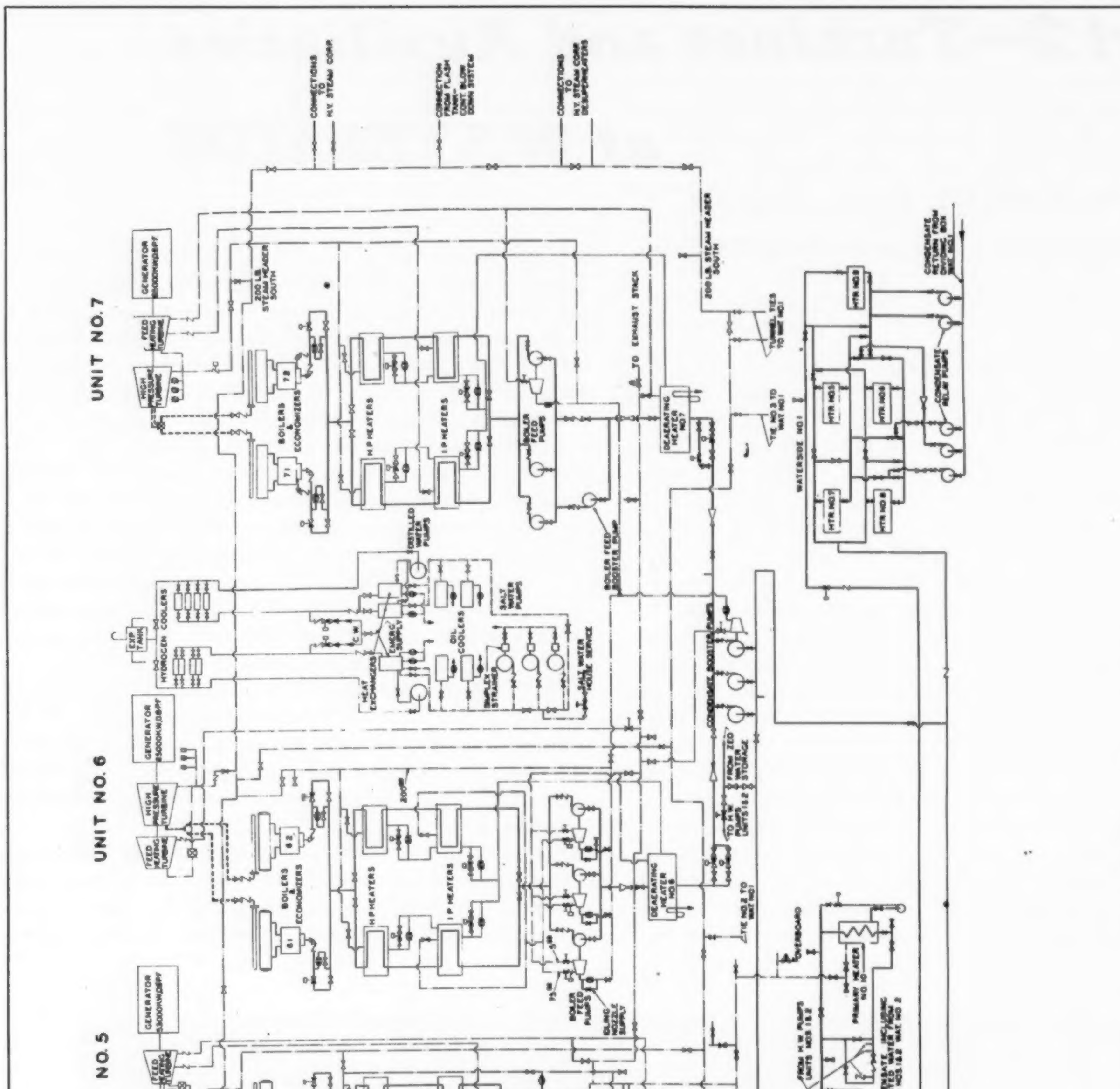

Fig. 10—General layout of all Waterside topping units

the low-pressure units, but this was found to be undesirable for several reasons. First, the bulk of the low-pressure machines are located in Waterside No. 1 at some distance from the heating apparatus in Waterside No. 2, thereby presenting a complicated and impractical layout. Second, the extraction openings in these older machines are too small to pass the required quantity of steam and the pressure would be too low for efficient use.

Unit No. 6 was manufactured by Westinghouse and consists of an all-reaction type, 16-stage, high-pressure section and a low-pressure section for feed heating, having a two-row impulse stage and 14 reaction stages. The low-pressure section exhausts at 5 lb per sq in. and acts as a reservoir of low-pressure steam for primary heating of the large makeup required because of the N. Y. Steam Corporation demands. The interesting feature of this unit is a separate forged-steel three-valve steam chest permitting a simplified cylinder casting design.

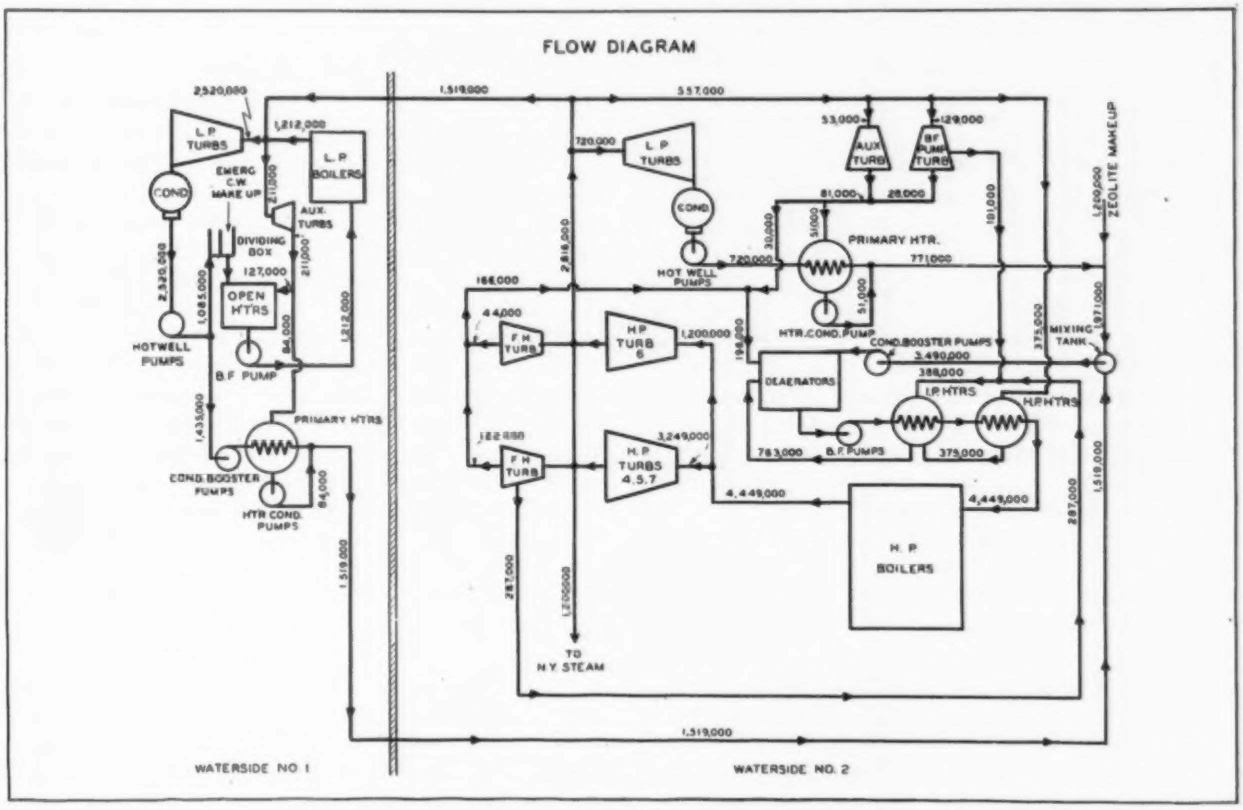

Fig. 11—Flow diagram showing steam distribution

Unit No. 7 is a General Electric, two-unit, impulse type, multi-valve machine similar to but larger than the previous turbine No. 5, installed in 1938. A 12-stage high-pressure element exhausts at 200 lb gage into the low-pressure section on the same shaft. This low-pressure section, or feed-heating turbine, is equipped with a bleed point at 75 lb for intermediate feedwater heating, and exhausts at 5 lb gage for primary heating. Both of the above units drive hydrogen-cooled generators, rated at 65,000 kw, 3600 rpm, 13,800 volts, 60 cycles at 0.8 power factor.

Back-pressure control is entirely in the hands of the high-tension operator who changes the load on the low-pressure units to maintain approximately 200 lb in the low-pressure steam system. Although the topping units are equipped with back-pressure regulators, these are set to act merely as upper limit controls.

Each of the topping machines is equipped with a load-limit control. This device permits the operator to limit manually the opening of the inlet valves to correspond with the number of boilers in operation, and, when on one boiler, to prevent pulling more steam than the boiler can deliver.

The basic design of the latest units does not differ to any great extent from the first two, and the only change of interest was in the method of support. The turbine foundations of the first two machines were tied into the building steel to obtain greater stability. Investigation of stub-shaft coupling failures indicated the possibility that turbine misalignment was caused by the changing position of the building steel, adjacent to the high-pressure boilers. All four foundations were subsequently isolated by cutting the ties to the building steel, and the original difficulties have apparently disappeared.

The newer units have been equipped with supervisory instruments of improved design, and protective devices, such as spindle axial-position indicators and thrust-bearing temperature alarms have been added.

The feedwater heating system follows the original plan very closely and centers in the Waterside No. 2 Station. Condensate from the low-pressure units in stations Nos. 1 and 2, including Zeolite treated makeup water sprayed into the condensers, passes through primary heaters, bringing the temperature up to 150 F, and then flows to a mixing tank from which headers supply condensate booster pumps. These pump the condensate to four deaerating heaters which are supplied with 5-lb steam from a common header which ties together all of the feed-

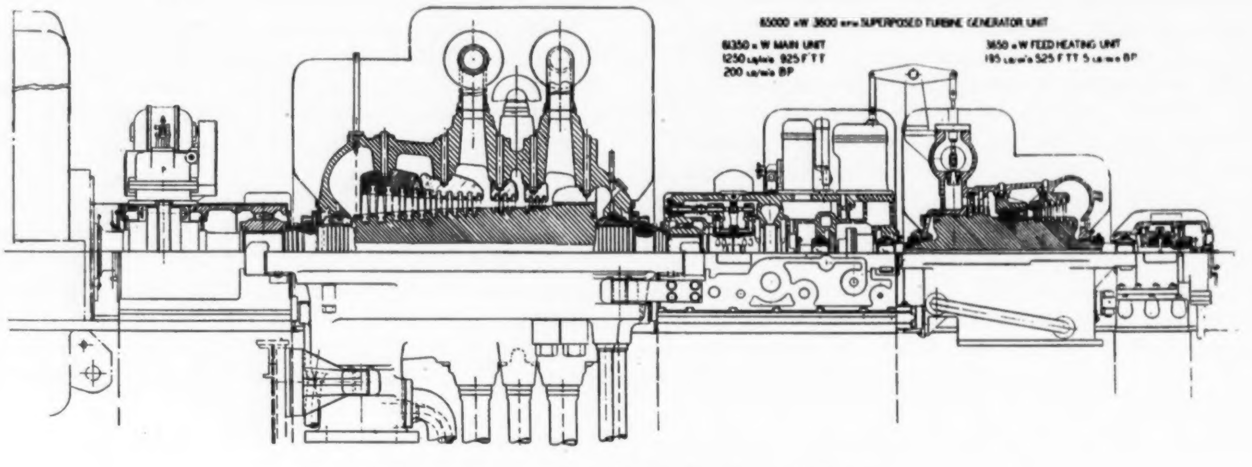

Fig. 12—Section through Westinghouse turbine

heating turbine and auxiliary exhausts. From the deaerating heaters, boiler-feed pumps take water at 220 F and discharge through the high-pressure feedwater heaters to the boilers.

In the latest installation there are three condensate booster pumps: two motor-driven and one turbine-driven spare. These pumps supply a common header feeding the deaerating heaters for Units Nos. 6 and 7. The turbine-driven unit is equipped with a quick-opening steam valve for emergency purposes.

The deaerating heaters are of the tray type, each equipped with two vent condensers, and two air-operated level-control valves, in parallel. To obtain improved control, one valve is arranged to handle up to half load, with the other taking over from this point to full load.

Each deaerator feeds a separate set of three boiler feed pumps. For the No. 6 boilers there are three turbine-driven barrel-type diffuser pumps: two for normal load and one spare. The drives are multi-stage and controlled by differential pressure regulators for variable speed operation. Steam at 200 lb per sq in. is supplied to these drives, a 75-lb controlled bleed furnishes intermediate pressure feedwater heating and the 5-lb exhaust is used for primary heating. The spare unit which may be any one of the three is started manually and they are all designed for quick starting. Alternately, an idling nozzle may be used for rolling the spare unit. The

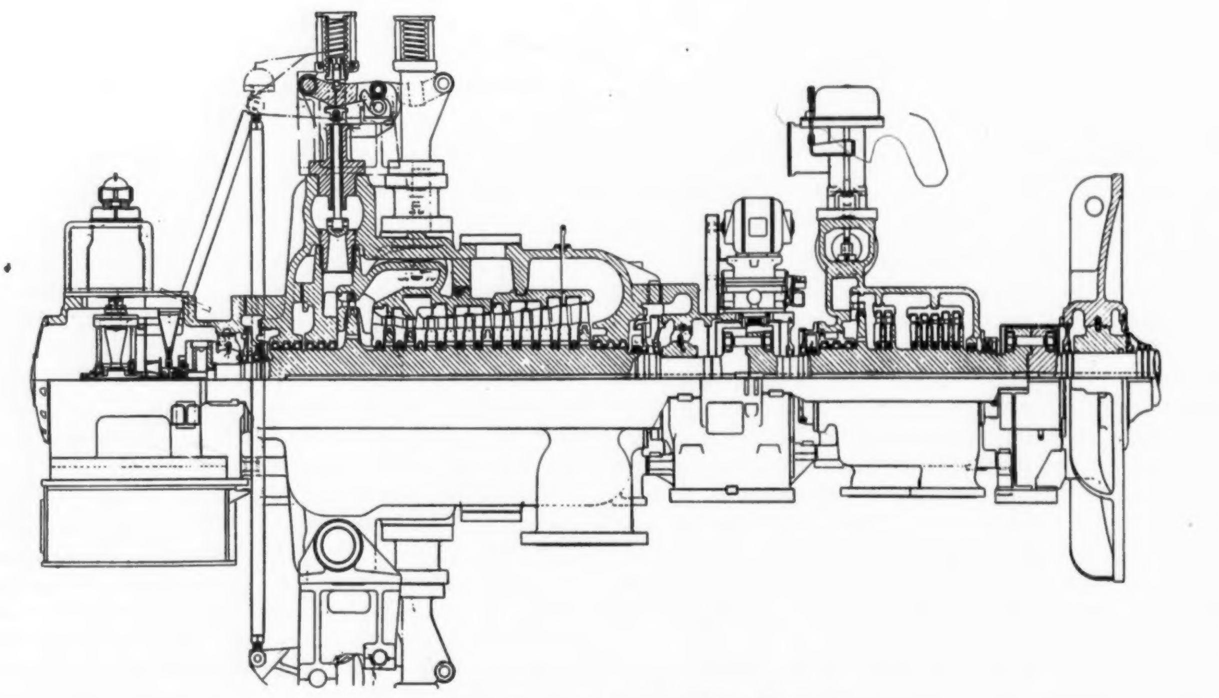

Fig. 13—Section through General Electric turbine

pumps are equipped with automatic opening bypass valves, designed to open at low flow and arranged for manual closing.

For the No. 7 boilers there are three boiler-feed pumps: two motor-driven and one steam-driven spare; and a motor-driven booster pump equipped with a variable speed electro-magnetic coupling. The motor-driven pumps are constant speed and of a size just shy of normal full load, in order to reduce, to a certain extent, light load throttling losses. The booster pump is designed for a flow equal to, and operates in series with, both the motor-driven main pumps and furnishes additional head to take care of any condition of operation between normal and emergency maximum loads. The boost required is obtained by the speed variation on this pump, directed from a differential pressure regulator, mechanically operating a field rheostat on the electric coupling.

Feedwater Heaters

The closed feedwater heaters on the discharge side of the feed pumps consist of two parallel sets of an intermediate and high-pressure heater for each of Units Nos. 6 and 7. This arrangement eliminates several costly high-pressure gate valves and bypass systems. In case an outage is necessary on any heater, due to leakage, repairs or cleaning, one set of heaters is isolated and full load can be carried on the other parallel set. The additional head required under this condition is made up on Unit No. 6 by speeding up the steam-driven boiler-feed pumps and on Unit No. 7 by the variable-speed boiler-feed booster pump. The heaters are of the horizontal, U-tube type, equipped with internal sub-cooling sections. The shells have wheels supported on rails for ease in removal. Suitable control valves maintain the condensate level in the heaters approximately halfway between the condensing and sub-cooling sections.

The high-pressure piping design and layout for the two latest units was not materially changed from that of the earlier units. However, the electric induction method of stress relieving welds was replaced, where clearances permitted, by a portable gas-fired furnace, using propane. As a result of the total absence of leaks in welds and closer supervision of the welding procedure, X-raying of joints was eliminated. Only low-pressure piping 10 in. and larger and all sizes of high-pressure piping were welded on the last installation.

Erosion of Induced-Draft Fans

Erosion of induced-draft rotors and housings has always presented a maintenance problem when burning solid fuels, but this has been intensified by increased rates of firing and the employment of high-tip speeds. Cinders from stoker firing cause more rapid wear than the finer ash from pulverized coal. However, with the increased use of cinder- and fly-ash recovery systems placed ahead of the fan, such wear is greatly reduced, although by no means eliminated. In general this arrangement will double the life of the rotor.

Fans that are riveted appear particularly susceptible to such erosion, for which reason welded construction is gaining favor. Moreover, with double-inlet fans having center plates the wear is likely to be concentrated at the junction of the blade with the center plate unless the construction be such as to avoid this. It is most desirable that the design be such as to distribute the wear as much as possible, for this will not only lengthen the period between outages but will also lessen the tendency toward unbalance and consequent vibration.

The usual practice is to employ steel-plate liners inside the scroll casings and to build up eroded rotors by welding. In some cases when radial-type fans are used, steel angles are welded at the junction of the rotor plate and blades and these angles are renewed as required. It is always necessary to rebalance a rotor after making such repairs.

In the recent report of the E.E.I. Prime Movers Committee on "Boiler Auxiliaries," statements from operating companies indicate varied experience in the extent of such erosion and the periods of renewal and repair. One company having a dust-recovery system ahead of the fan reports the replacement of wearing plates every 7 years; another after $4^1/_2$ years; and a third every $2^1/_2$ years. On the other hand, a company which has the fans ahead of the recovery system reports that half the vanes of the fans are replaced every year; and another with pulverized coal and no recovery system finds it necessary to build up the hubs, disks and blades about every three months because of excessive wear. In still another case, in which precipitators are placed ahead of the fan, no serious erosion has occurred in over 3 years' operation.

Power Production and Coal Stocks

According to figures just released by the Federal Power Commission, the electric energy produced for public use in January 1942 totaled 15,353,613,000 kwhr which represented an increase of 15.2 per cent over that for January 1941. The capacity of generating plants, as of January 31, 1942 is given as 44,237,596 kw, or a net increase of 213,377 kw during the month.

During this period electric utility plants consumed 5,918,373 tons of bituminous coal, 228,833 tons of anthracite (a decrease of 4.8 per cent from December), 1,865,768 bbl of fuel (a decrease of 4.6 per cent from December) and 17,168,537 mcf of natural gas (6.7 per cent less than December).

During January the coal stocks decreased 1.5 per cent, but were sufficient to last 66 days for bituminous coal and 163 days for anthracite.

40,000-Hp Motor Drives Propeller

The new wind tunnel at Wright Field, Dayton, Ohio, which is nearing completion for testing large size airplane parts and models, is built for wind velocities of 400 mi per hr. This air is circulated by two propeller assemblies mounted on a common shaft and operated in series to produce the necessary high pressure. The propeller assembly is driven by a Westinghouse 40,000-hp, variable-speed, wound-rotor type induction motor which has a top rotational speed of 300 rpm. It is the largest unit of its type built to date. The diameter of the propellers is 40 ft.

Cleaning the Regenerative-Type Air Preheater

A practical discussion of the methods employed to maintain the heating surfaces of Ljungstrom air preheaters in condition for best efficiency and to avoid corrosion; also, the removal of soot accumulations incident to the burning of low-grade fuels. Included are the application of soot blowers, hand lancing and washing by means of integral water jets. The frequency of these operations depends entirely on local conditions.

By JOSEPH WAITKUS

The Air Preheater Corporation

THE employment of higher steam temperatures and a demand for high unit efficiency have been responsible for widespread use of heat-recovery equipment of which the air preheater is an important part. Moreover, it is essential that operation continue over long periods without interruption despite the fact that low-grade coal is used in many cases.

Low-grade fuels are likely to contribute to the formation of deposits and to corrosion through the introduction of sulphur in the presence of moisture, particularly where operation is at low capacity for extended periods which may result in temperatures below the dewpoint. Various means have been adopted to combat this tendency, such as cold air bypassing and hot-air recirculation to avoid corrosion, and soot blowing or washing to remove deposits.

The Ljungström regenerative type of air preheater, which is fabricated in both the horizontal and vertical designs, is particularly suited to such control of corrosion and means of removing deposits. Its basic principle of design presents a homogeneous structure of plates, split into layers continuously absorbing and releasing heat, and because all the heating surface passes through all the gas and air, localized heating or cold spots are eliminated. That is, no portion of the heating surface differs in temperature from that of any other portion at the same point in the gas or air stream. Also, due to the short and direct path of travel of gas over the heating surfaces, the accumulation of deposits presents less of a problem. The present discussion deals with means for removal of deposits, with special emphasis on precautions that will assure most effective cleaning.

Soot-Blower Applications

The oldest and most generally employed method of keeping heating surfaces clean in a regenerative-type air preheater is the steam soot blower. Compressed air has been employed successfully in a few cases, but its adaptability is limited to special conditions.

Typical steam soot-blower installations as applied to horizontal and vertical air preheaters are shown in Figs. 1 and 2, respectively. They consist essentially of two nozzle pipes and four valves, one nozzle pipe being located at the gas outlet and the other at the gas inlet.

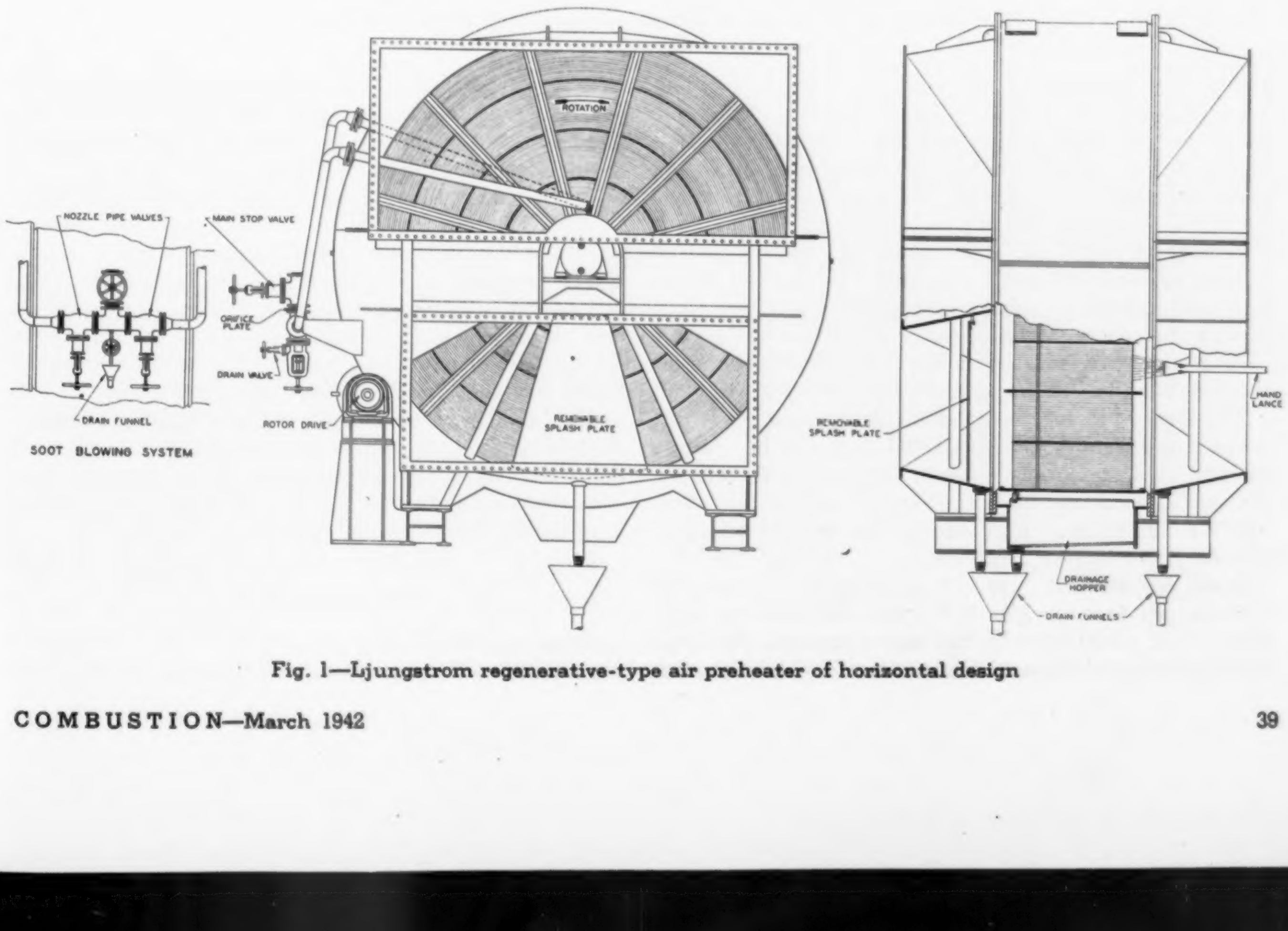

Fig. 1—Ljungstrom regenerative-type air preheater of horizontal design

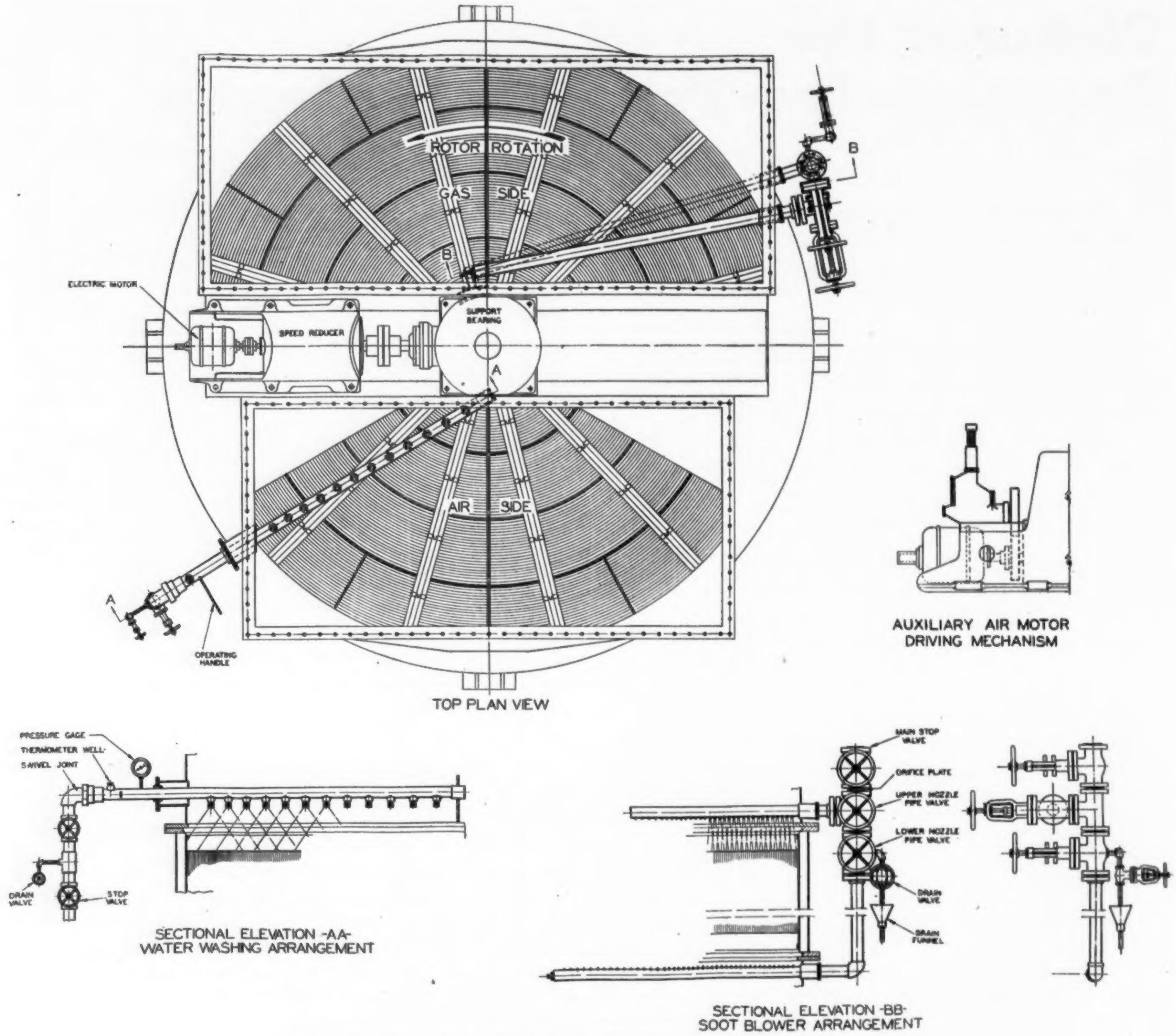

Fig. 2—Plan view of Ljungstrom regenerative-type air preheater of vertical design equipped for soot blowing and washing

Each has a series of nozzles (Fig. 3) of the converging type, designed to furnish a high velocity steam jet. These nozzles have a high resistance to erosive action of the steam. Their number will range from 10 to 60, depending upon the size of air preheater, and their spacing is such as to distribute steam in accordance with the rotor velocity and the amount of heating surface passing under each nozzle. In other words, the nozzle spacing near the periphery of the rotor is closer than toward the center. The steam consumption of the soot blowers will vary from 1 to 9 lb per sec, depending upon the size of air preheater, pressure and temperature.

The steam pressure in the soot blower element is important and should not exceed 200 lb per sq in. While the preferred pressure is between 150 and 175 lb, a lower pressure is sometimes necessary and is permissible. Too high a steam pressure may damage the seals attached to the radial diaphragms of the rotor.

There are several types of seals in general use, as indicated in Fig. 4. The bulb type which is now most widely used permits the highest steam pressure, although the labyrinth seal when fabricated from $^{1}/_{16}$-in. aluminum bronze will also withstand high pressure. On the other hand, if made of No. 22 gage sheet steel the pressure limit drops to about 100 lb. The single-leaf and single-spring seals are limited to 125 lb.

Attention is called to the valve arrangement indicated in Figs. 1 and 2. It will be noted that two stop valves are provided, one for each nozzle pipe.

The purpose of two nozzles pipes is obvious. The heaviest deposit tends to accumulate at the cold end, and by providing a nozzle pipe at this location the steam jet will be close enough to shatter and dislodge the deposit which can then be blown away in the direction of flow of the flue gas by the nozzle at the hot end. It will be noted that the nozzle pipes are not directly in line but are offset slightly. This permits free action for the steam over the heating surface and avoids plugging the nozzles in one pipe with deposits loosened by the other.

Soot-Blowing Routine

Frequency of blowing is dependent upon conditions pertaining to the individual installation. Rarely is it

necessary more than once every shift and in many cases a longer period elapses between blowing. The nozzle pipe at the hot end is used, so that the blow will be in the direction of flue gas travel. That at the cold end should be used only if actual trial shows that the resistance through the air preheater can be lowered by blowing from the cold end after first blowing from the hot end. Both nozzle pipes should never be blown simultaneously as this will increase the pressure drop in the supply pipe with consequent reduced pressure at the nozzles and result in poor cleaning. Where unusual fuel or operating conditions prevail it is well to consult the air preheater manufacturer as to such routine.

So far, only two valves have been mentioned. There is also a main stop valve to isolate the soot-blowing system from the source of steam supply. Inasmuch as the supply pressure is usually higher than that permissible for the soot blowers an orifice plate is inserted directly after this stop valve.

A drain valve is also provided in order to assure dry steam for soot blowing. The importance of opening the drain valve prior to operating the soot blowers cannot

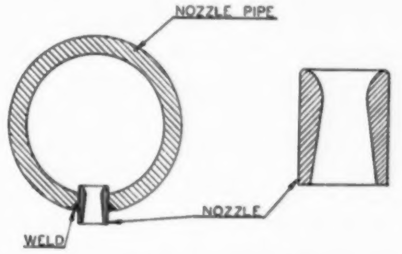

Fig. 3—Section through soot-blower nozzle

be over-emphasized. The drain should be provided with an open discharge directed into a funnel which will enable the operator to make sure that the system is free of entrained moisture before he opens the valves to the nozzle pipes.

Although saturated steam is generally satisfactory for blowing and is so used in many installations, preference should be given to superheated steam, if available. This is because entrained moisture, coupled with a high velocity discharge, will tend to produce erosive action, and, secondly, a mixture of moisture and soot particles that may not be blown clear of the heating surfaces may adhere and subsequently dry to form nuclei for further deposits which will build up and ultimately produce clogging.

Even though the steam be superheated and the lines completely drained of condensate there is still the possibility of condensation from moisture in the fuel or from

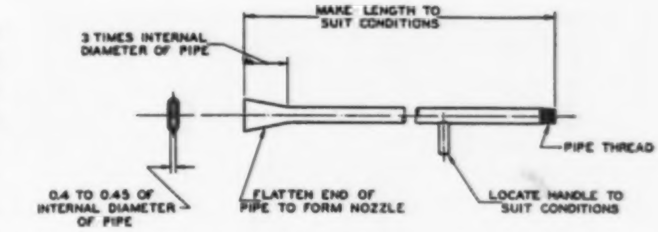

Fig. 5—Typical hand lance

deslagging operations in the furnace. In some cases this may contribute to a rate of deposit beyond the ability of the ordinary soot blower to remove, and it becomes necessary to resort to periodic washing.

Washing the Heating Surfaces

Nearly all deposits found on the surfaces of air preheaters are soluble in warm water,[1] hence washing at definite intervals makes it possible to operate air preheaters under deposit conditions too severe for the ordinary soot blower. The washing operation can be accomplished by either of the two following methods:

In the first method the heater is shut down and after it has cooled sufficiently for the operator to enter the housing, the surfaces are hand-lanced with water at 50 to 125 lb pressure and 150 to 175 F. If the lance is held close to the heating surface and one small area washed at a time complete results can be obtained. It is important that all corners and recesses, especially around the seals, be thoroughly cleaned and it is well to continue the washing until certain that the acid film is completely removed. A typical lance is shown in Fig. 5. Such washing should never be attempted with the rotor revolving under its own power. It can be turned by means of a hand crank so that one sector at a time can be washed. This method is applicable to either a vertical or a horizontal preheater.

As already mentioned, this requires the complete shutdown of the unit served by the air preheater unless provision has been made to isolate the air preheater by bypassing the gas and air around it.

In the second method the air preheater is provided with a water-washing arrangement somewhat similar to that employed for soot blowing. It does not require the operator to enter the housing and can be accomplished while the rotor is revolving at reduced speed. A typical arrangement for water washing is shown in Fig. 2. It should be mentioned, however, that such an integral water spray is applicable only to vertical air preheaters.

[1] The few exceptions may be removed by first treating with a solvent and then washing with warm water.

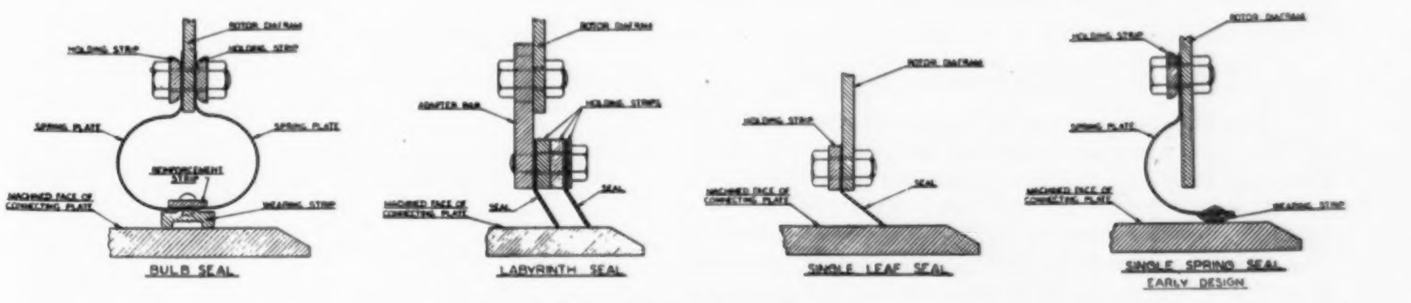

Fig. 4—Types of seals in general use

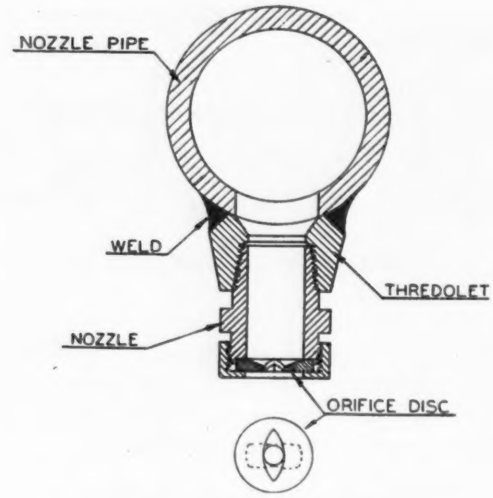

Fig. 6—Section through spray nozzle

With the horizontal type the absence of gravity flow to carry off the sludge would make it necessary to depend on a very large amount of water and higher pressure than is desirable. Therefore, hand lancing is the most practical means of washing air preheaters of the horizontal type.

The integral water spray consists of a nozzle pipe to which a series of nozzle assemblies is welded. These nozzles are designed to provide a flat fan-shaped spray and the sprays are arranged to overlap. Water consumption depends upon the size of nozzle orifice, number of nozzles, pressure and temperature. With 3 to 16 nozzles, a pressure of 30 lb per sq in. and a temperature of 175 F, the $^1/_4$-in. orifice has a water consumption ranging from 25 to 125 gpm whereas with a $^3/_8$-in. orifice the range would be from 50 to 275 gpm. Fig. 6 is a section through a spray nozzle.

As indicated earlier, the effectiveness of washing depends upon the care with which each sector is treated. It is therefore necessary to reduce the rotor speed for the integral water spray for the same reason mentioned under hand lancing. The rotor may be revolved slowly by a hand crank attached to the shaft extension or a small air motor may be employed for this purpose (see Fig. 2).

The integral water spray has several advantages. Operation of the equipment is interrupted for a short period only and loss of time in waiting for the equipment to cool, as in the case of hand lancing, is eliminated. From one-half to one hour is usually sufficient for a thorough cleaning. Steam generating units equipped with two regenerative-type air preheaters can continue operation at 50 to 70 per cent of normal capacity with all the flue gases passing through one preheater while the other is being washed.

Collecting and Draining Wash Water

An important adjunct to washing is means for collecting the wash water and sediment and draining it away. The rotor housing and duct connecting plates of a horizontal air preheater are provided with pockets into which the water settles and is then drained to the sewer or a sump. A plate is also provided to deflect the water after it passes through the heating surface and to keep it from splashing over the interior of the duct. In the case of vertical air preheaters the pockets must be provided in the ducts. It is also desirable to provide pockets in the ducts with horizontal preheaters to supplement those mentioned. Examples of duct pockets are shown in Fig. 7. Spray nozzles are so located as to permit the water to drain out completely before the rotor re-enters the gas side of the preheater, provided the speed of rotation is slow enough.

In some cases where the necessity for washing was not anticipated initially and hand lancing subsequently became necessary, through the use of a different grade of fuel, it was found difficult to provide pockets in the ducts without considerable expense and inconvenience. Solution of the problem was found in the construction of a collapsible trough which could be easily handled through the manhole opening in the duct. Upon completion of the washing operation the trough is either disassembled and removed or it can be fastened to the inside of the duct where it will cause the least disturbance to gas or air flow. In the latter case the trough can be welded.

Conclusions

To wash heating surfaces satisfactorily plenty of hot water must be used and sufficient time taken to permit complete drainage. Too little water may lead to the formation of a strong acid solution if the deposit contains considerable sulphur and this acid will subsequently cause corrosion. Also, with too little water the deposit may be carried deeper into the heating surfaces and lodge there to obstruct the free flow of air and gas. In this respect hand lancing has an advantage because sufficient water can be concentrated at any point.

To say definitely which of the two methods is best suited to meet a particular condition is difficult. Experience indicates that it is desirable to equip every air preheater in a coal-burning installation with a soot blower. With natural gas alone there are no deposits worth considering and soot blowers can therefore be omitted. In many cases, steam generators are designed to burn two or three fuels to provide greater flexibility and economy. In such cases, a critical study should be made of all the fuels to determine their relative characteristics in the matter of deposits. The one producing the worst condition should be the determining factor in the selection of the proper cleaning procedure.

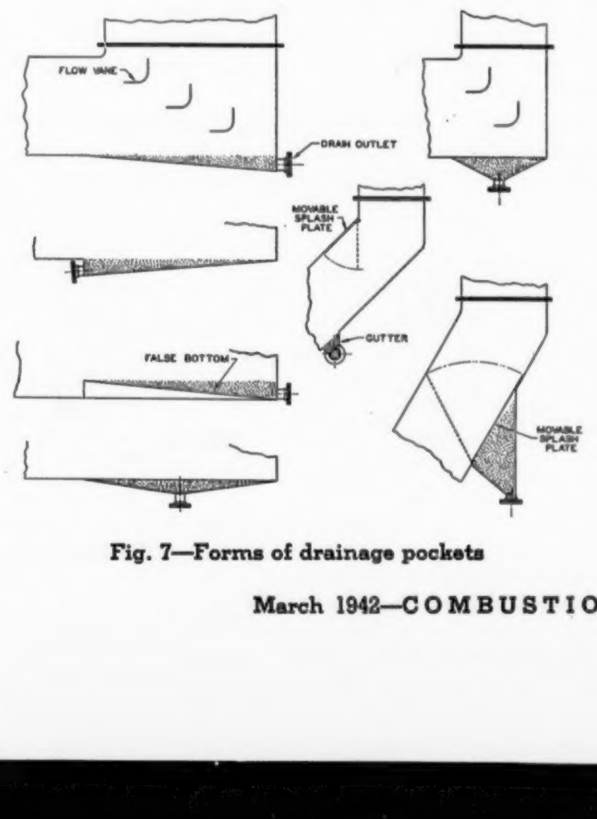

Fig. 7—Forms of drainage pockets

The author reviews progress in steam-turbine design as closely related to advances in metallurgy, discusses creep, shows how expansion is compensated, explains blade resonance, describes means for handling the problem of moisture and blade erosion in the low-pressure stages and illustrates how cyclic vibrations of the generator are overcome.

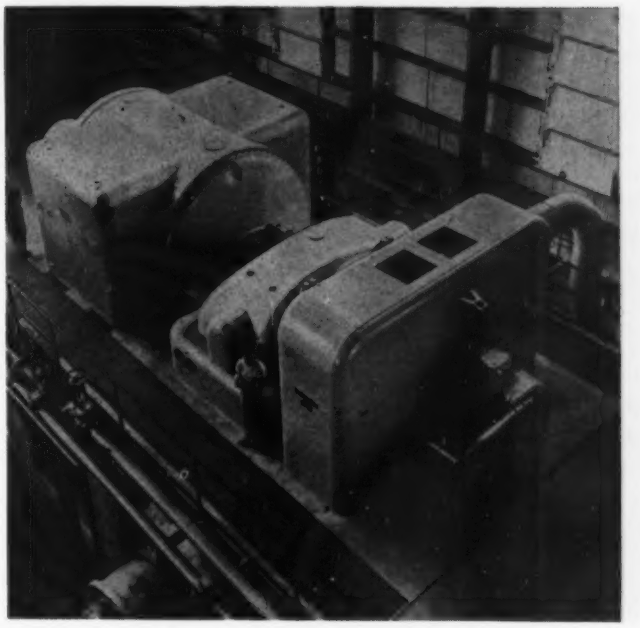

Fig. 1—Late design of 25,000-kw, 3600-rpm single-casing turbine with hydrogen-cooled generator

*Modern Turbine Developments**

By J. R. CARLSON, Engrg. Dept.

Westinghouse Elec. & Mfg. Co.
South Philadelphia Works

SINCE the development of the steam turbine has so closely depended upon the development of suitable materials turbine progress may be divided into three general periods corresponding with three general periods of progress in metallurgy. The first may be termed that of "cast iron." Although cast iron was entirely suitable for the early turbines, it was not long until this material proved to be the limiting feature of further advancement. Use of cast iron placed a ceiling on the steam temperature at around 450 to 500 F. Temperature above this limit caused the cast iron to grow with resultant distortion and seizing of parts.

The second general period was that in which steel castings and steel forgings were made available to the industry. The use of these materials raised the maximum limits of the steam temperature very appreciably.

The third period was that in which modern alloys such as carbon-molybdenum steel castings and nickel-chrome-molybdenum forgings were developed. These materials again permitted a vast improvement in operating temperatures and pressures and sizes. The development and adoption of these materials bring us into the present-day art of turbine building.

During the period of cast iron, the 1800-rpm machines increased in size from 1000 kw in 1900 to about 10,000 kw in 1908. Use of the 3600-rpm turbine was so insignificant that it is hardly worthwhile mentioning. The inlet steam conditions were low, being limited largely to pressures of 175 lb and temperatures of 350 to 450 F. Heat rates were, of course, out of sight so that the less said about them the better.

The development and adoption of reliable steel forgings and castings paved the way for increasing the inlet steam conditions. These cast-steel parts were first used on throttle valves and steam chests which meant that the increase in steam conditions was rather gradual. The better stress properties of steel also provided the way for the large increase in the physical size of turbines. During the early twenties 1800-rpm turbine-generator units as large as 60,000 kw were built for inlet steam conditions of 250 lb gage and 550 F. A gradual decrease in heat consumption was brought about by improvement in steam conditions and in efficiency of the turbine. The sharp reduction in heat consumption which occurred in 1922 resulted from adoption of the regenerative heat cycle. This second period of development ended in about the year 1928. The size of the 3600-rpm turbine grew to 10,000 kw, which was then considered quite an outstanding engineering achievement. The 1800-rpm turbine by various arrangements of shafts and multi-exhausts was produced in capacities as high as 165,000 kw.

Thermal studies showed that the use of higher steam pressures and temperatures would result in improvement in operating economy. However, since materials available during the middle twenties limited the upper temperatures, it was possible to achieve operating economies only by increasing the steam pressure. This period is characterized by the installation of several machines designed for steam conditions of 1250 lb per sq in. gage and 750 F total temperature. These steam conditions resulted in excessive moisture and erosion of the exhaust blading of condensing turbines. To overcome this difficulty, it was necessary to resort to interstage heating. These turbines operating at high-steam pressures with reheating between stages produced an improvement in heat rates, but were penalized by the added complication of the boiler and steam piping. Most engineers preferred to eliminate interstage reheating if similar results could be obtained from some simpler arrangement.

* Abstracted from a recent talk before the Metropolitan Section A.S.M.E.

The period from 1928 to 1932 was a transition stage between the age of cast steel and that of highly alloyed metals. During this period, a few condensing turbine-generator units were built for steam conditions of 650 lb gage, 825 F. Also, a few 3600-rpm superposition machines in ratings varying from 10,000 kw to 18,000 kw were built. These machines were the forerunners of today's designs.

Metallurgical Developments Responsible for High-Steam Temperatures

During 1935 and 1936 metallurgical developments and tests of the highly alloyed metals had progressed to the point where it was shown they could safely be used with steam temperatures as high as 925 to 950 F. The first applications of these new alloys were in modernizing old stations by means of superposition. The gain in heat rate can be clearly seen in Fig. 2 by following the dotted line which merely moves the 1915 heat rate over to 1935. The gain from superposition is represented by the drop in the vertical dotted line.

Superposition helped to solve the problem of old and inefficient steam stations, but it brought with it another one, namely, the problem of heating the feed to the new boilers. Since many of the old condensing turbines had no means of extracting steam for feedwater heating some other means had to be developed. This was rather neatly solved by using non-condensing or non-condensing extraction turbines for driving auxiliaries such as the boiler feed pump. Not only did these auxiliary steam drives provide a means for heating the feed to the boiler but they also provided for a further decrease in the overall station heat rate.

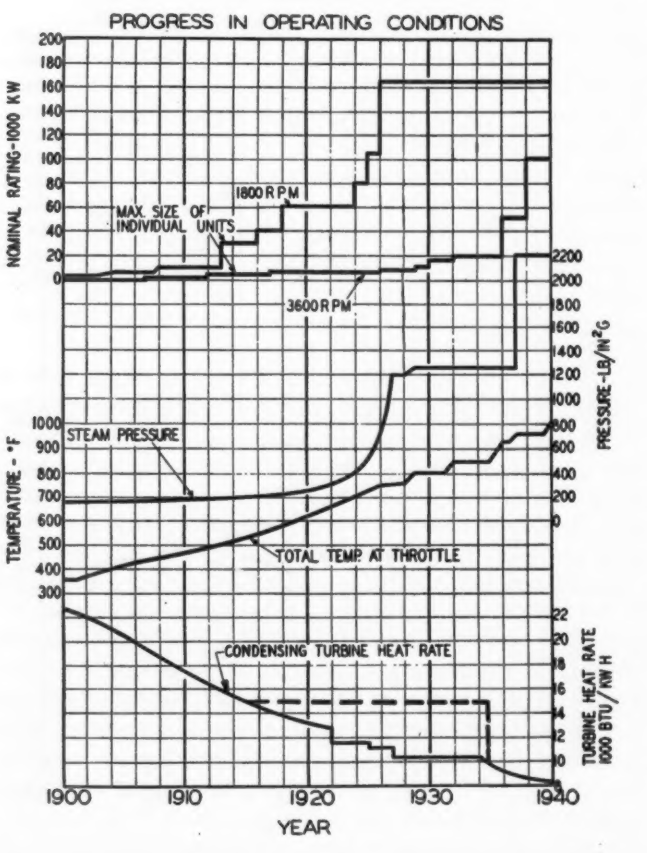

Fig. 2—Chart representing progress in operating conditions

Since metallurgy has played such an important part in the design of the present-day steam turbine, it might be well to examine characteristics of metals and particularly those that affect turbine design. When temperatures exceed 750 F the phenomena of creep, that is, the growth of materials at elevated temperatures, and constant stress can no longer be ignored. In designing

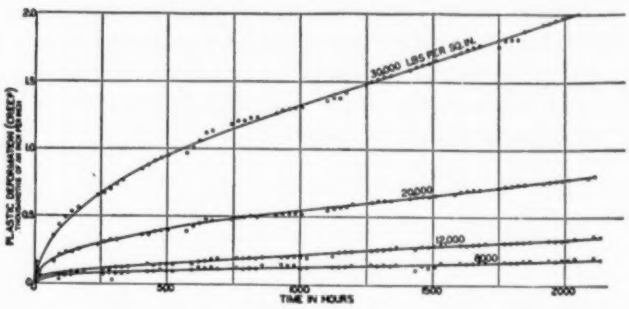

Fig. 3—Creep curves for nickel-chrome-molybdenum steel at 932 F

turbines for use at high temperatures, the engineer must first have a thorough knowledge of the materials to be used. To design adequate structures he must know the rate of permanent deformation as a function of temperature and allowable stress. Data on creep rates have been obtained from careful investigations and tests. Creep investigations must be carried on over a long period inasmuch as time is an important factor. Batteries of creep testing machines are used for carrying out these investigations. Several specimens are mounted in each machine and are loaded by lever and weight combinations. The specimen is maintained at a constant elevated temperature and the elongation of the test piece is accurately determined by a special telescopic measuring device. Fig. 3 shows creep curves for nickel-chrome-molybdenum steel at 932 F.

The rate of creep varies with time. Since we are interested in the creep rate at the end of some 100,000 hr the need for long-term tests is readily appreciated.

Development in Bolting

Closely related to creep but different enough to be annoying is the relaxation phenomena encountered in bolts at elevated temperatures. This is the name given to the property of a stressed bolt to relax gradually its holding power on the flange. The bolt in the cold and unstressed condition has a length as indicated in Fig. 4. When making the joint the bolt is heated until the length is equal to that of the flange, and the nut is turned down by a light wrench. Then upon cooling, the bolt is stressed by an amount equal to the reduction of length (shown exaggeratedly in Fig. 4). The bolt then proceeds to relax its holding power as a function of time and initial stress. If turbine casings are to be held tightly together so as to prevent steam leaks, it is important that the relaxation property of bolting be carefully investigated and suitable materials developed. Such tests are made by automatic machines, the actual conditions existing in the bolt in the turbine flange being simulated by automatically reducing the stress to maintain a fixed length as the bolt relaxes. The machine then automatically plots the reduction of stress with time.

Development of bolting has been a major problem, particularly as materials with high-relaxation stress values were in the majority of cases found lacking in other essential properties. Practical experience has indicated that high-temperature bolting should not be subjected to heavy wrenching. The better practice is to expand the bolts by means of heating elements and then tighten the nuts by light wrenching.

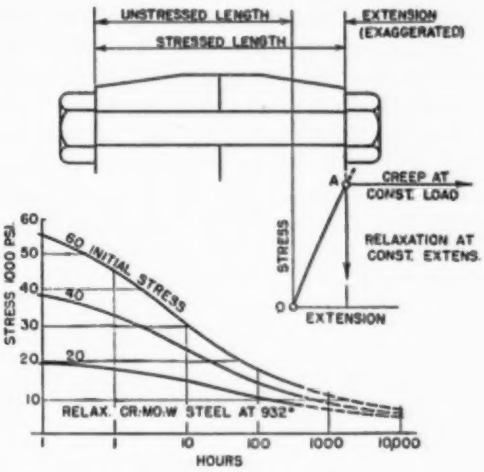

Fig. 4—Bolting and relaxation curves

Testing Methods

Development of X-ray and Gamma-ray processes has also contributed to the investigation of materials. Such equipment has been used extensively to investigate the soundness of castings and forgings and to check the quality of welds.

Higher operating steam temperatures have indicated strongly the desirability of using solid alloy steel forgings for turbine rotors. While these solid alloy rotors are more difficult to produce, their use has been highly successful. No small part of this can be attributed to the development of effective methods of testing. In addition to the usual chemical and physical tests made on the rotor forgings there is the heat indication test. This test is applied to indicate that the internal stresses resulting from the forging process have been removed by annealing. If these internal stresses are not removed the rotor upon being heated would act like a piece of bimetal, that is, it would bend as it heats up and straightens out again upon being cooled.

A rotor in undergoing such a heat indication test is mounted on lathe centers and enclosed by a box. It is slowly rotated while being heated to a temperature in excess of its maximum operating temperature. During the heating and cooling periods careful checks are made for distortions. Fig. 5 shows a rotor being so tested.

Compensating for Expansion

To generate power a turbine must run, and in order to continue to run, the various parts must stay somewhat near their intended positions. Assuming a turbine of approximately 15 ft in length with an operating temperature of 900 F at the inlet end and 100 F at the outlet, it will be found to expand in length approximately $^1/_2$ in. over that at room temperature. This axial expansion of approximately $^1/_2$ in. must be carefully accounted for during the starting, running and shutting down operations. Furthermore, this expansion must be permitted to occur without restrictions such as cause distortions. Since this expansion cannot be eliminated it becomes necessary to guide or to control it so that expansion occurs in a manner that is not detrimental.

The problem of axial differential expansion is best solved by choosing the point of fixation between the rotor and stator near the critical or hot end and the point from which expansion starts and then provide ample axial clearance between the stationary and rotating parts. The point of fixation is, of course, the thrust bearing.

In providing for this controlled axial and transverse expansion, one end of the cylinder, preferably the cold end, is keyed to the foundation to prevent axial motion or motion in a direction parallel to the shaft. The opposite end, or hot end, is left free to move in an axial direction but is restrained in a transverse direction. Likewise, transverse motion at the exhaust end is maintained by this center key. When steam is admitted to the cold machine the cylinder, being anchored at the exhaust end, tends to expand toward the opposite end and pushes the rotor with it. This tends to decrease the axial clearance between the stationary and moving parts. However, the rotor is expanding more rapidly at the same time and more than counterbalances the cylinder expansion and indicates the necessity of having ample axial clearance.

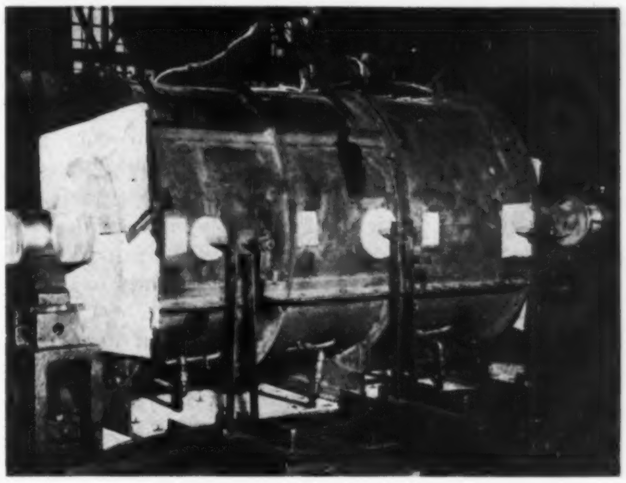

Fig. 5—Rotor undergoing heat indication test

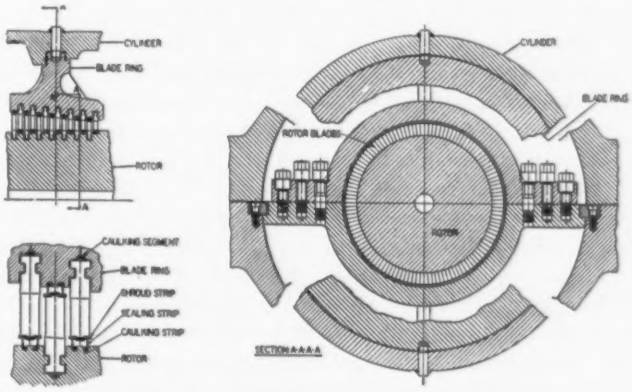

Fig. 6—Showing application of blade rings

Another form of expansion which occurs is differential radial expansion. It is obvious that if during the starting phases the rotating element grew radially faster than the stationary element there would be danger of rubbing. Also, in shutting down, the stationary element may radiate heat at a more rapid rate than the rotating element and exert a clamping action upon the rotating element. Of course, it would require unusual differential expansion before rubbing actually occurred. However, it is well to recognize the problem and design so as to minimize the action. This is accomplished by means of separate blade rings as shown in Fig. 6. These blade rings are supported by lugs at the horizontal joints and are held in correct alignment by pins at the top and bottom. With this arrangement the blade rings are free to expand uniformly in all directions upon heating much as a balloon does upon being inflated. Steam is allowed to flow around the blade rings which causes them to expand at very nearly the same rate as the rotor. Another desirable characteristic of the blade rings is that they can expand freely with almost a complete absence of distorting forces upon the outer casing. Leakage past the blade rings is prevented by interstage sealing rings.

Fig. 7 shows a typical steam valve and diffuser-type seat. Due to the rapid flow of hot steam through the diffuser seat in starting, the diffuser expands at a more rapid rate than the body of the steam chest and destroys the press fit which held the diffuser in place. Then due to the dynamic force of the flowing jet, the valve seat would start to back out. This difficulty was corrected by screwing the valve seat into the turbine cylinder. The screw fit is loose to accommodate the radial expansion of the valve seat and yet hold it in place. A flexible lip at the top is welded to the steam chest body and prevents leakage. A close fit at the bottom of the valve seat guards against any possible side thrust resulting from the steam flow.

Turbine Blade Resonance

Turbine blades may be conveniently divided into three groups, the mark of distinction being the natural frequency band into which each group falls. This first group is normally the first stage and has a natural frequency of 25,060 times the running speed which corresponds to 1500 to 3600 cycles per second. The second group which is the intermediate blading has a natural frequency in the neighborhood of 8 to 20 times the running speed, or 480 to 1200 cycles per second. The exhaust end blading is the third class and has low natural frequency.

The first type of blade is commonly known as Curtis or Rateau blading, and this stage operates with a variable arc of admission in order to maintain the efficiency of the turbine over a wide range of load. The ability to produce a satisfactory design of this type of blading depends upon sufficient knowledge to predict the build-up of stresses in them under resonant conditions. Studies conducted on a full-scale experimental unit have shown that it is impractical to design and build blades in which the natural frequency has been selected so as to be out of resonance. Since the natural frequency of these blades is in the neighborhood of 1500 to 3600 cycles per second, any variations in manufacturing tolerances would change their natural frequency appreciably. It has been anticipated that variations in natural frequency due to manufacturing tolerances may amount to approximately 10 per cent or 150 to 360 cycles. This percentage not only results from machining tolerances but also temperature changes and is therefore beyond hope of control, as frequency changes much smaller than the values indicated are enough to place a blade in resonance. It has been shown that changes as small as 2 per cent are sufficiently great to bring a non-resonant blade into resonance.

Our experience and investigations have shown that not only the magnitude but also the character of the steam loading must be known in order to establish the build-up factor. Only after these factors have been carefully determined can blades be designed to be safe under resonant conditions. This information has been obtained from a 10,000-kw development turbine operating with initial steam conditions of 1250-lb gage, 900 F and variable exhaust pressure.[1] The turbine is provided with both a water brake and a generator so as to allow flexibility in analysis. The water brake permits operation at variable speeds and the generator allows life tests to be run without wasting energy.

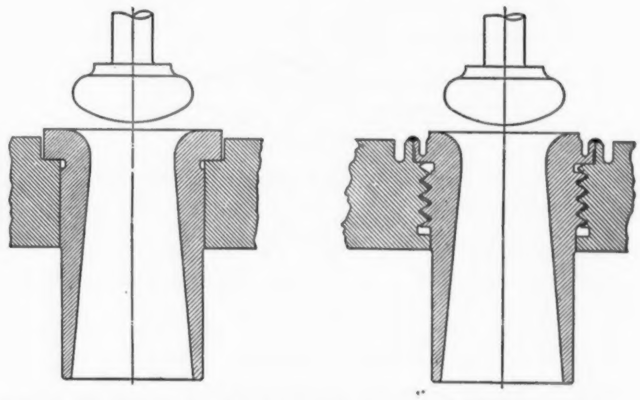

Fig. 7—Typical steam valve and one with diffuser-type seat

The intermediate blading is probably the least troublesome of all. It is, of course, designed for full admission. Once this design has been worked out to be sufficiently adequate to take care of the steam load and centrifugal load the only other point of consideration is that of the blade wake resonance. Suitable recognition must be given to the disturbances in the steam flow caused by extraction openings or exhaust openings on tandem turbines.

The exhaust-end blading is in the low natural-frequency class. The basic problem was to predict and control the natural frequency of the blades as well as to predict and control the harmonics. Solution of this problem was accomplished some time ago and was one of the outstanding contributions to turbine engineering. Once having established the basic knowledge the design problem resolved itself into proportioning blades, blade roots and rotor so as to keep within safe stresses.

Combating Moisture and Erosion

Increasing steam pressures and increasing turbine efficiency have heaped new problems upon low-pressure blades. Steam conditions of 650-lb gage, 825 F, 29-in. vacuum result in a moisture content in the exhaust of approximately 13 per cent. Steam conditions of 1250-

[1] See "Superposed Turbine Blade Research," by F. T. Hague, COMBUSTION, March 1940, pp. 28–31.

lb gage, 900 F and 29-in. vacuum produce a moisture content in the exhaust blading of approximately 15 per cent. Accompanying this increase in moisture in the low-pressure end has been a gradual rise in the length of the blades and an increase in rotor diameter. The result is that blade velocity has risen from 900 or 1000 ft per

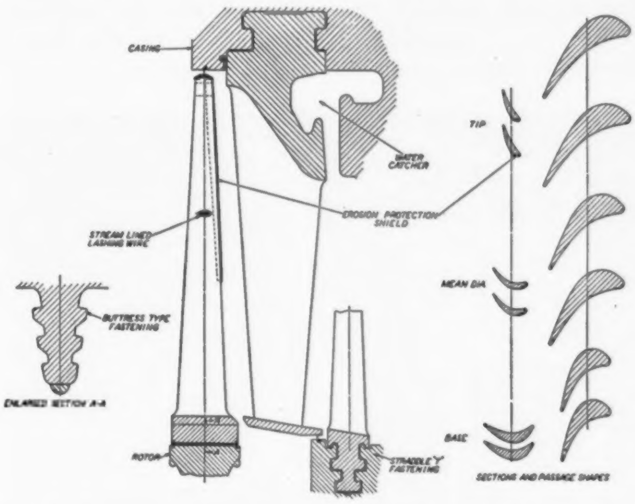

Fig. 8—Low-pressure exhaust-end blading with moisture-alleviating devices

sec to 1250 ft per sec. These factors have all combined to make the problem of low-pressure blade erosion a rather serious one. The solution of this problem has been accomplished by taking advantage of three mechanical devices and one thermodynamic principle. It has been recognized that by improving the flow conditions through the blading a more uniform distribution of the destructive water drops could be obtained. In other words, the concentration of the water droplets over the high-speed outer periphery of the blades would be alleviated. This is accomplished by the use of the constant circulation blades which recognizes the vortex effect of the flowing steam and which establishes a smooth axial flow.

The three mechanical devices which are used to alleviate the moisture problem are water catchers, streamlined lashing wire and stellite shields on the blades (see Fig. 8). Water catchers have been found very effective in removing the free moisture present in the stream. Water is thrown off by centrifugal action of the steam flow and rotating blades and is caught in suitable cavities in the cylinder from which it is drained to the condenser through an orifice.

Where the blade is of sufficient length to require lashing wires in addition to the shroud band this wire is made of a tear drop or streamlined section. This effectively breaks up the water concentration behind the lashing wire and at the same time minimizes the cutting on the inlet edge of the adjacent following row of blades.

The high-velocity low-pressure end blades are further protected around the inlet edges by stellite shields silver-soldered to the blade section. The stellite, which is much harder than blade material itself, has been found to be the most suitable and effective material for protecting the blading against erosion. Stellite shields have been used for a number of years. The combination of these four factors has been very effective in reducing the erosion of high-speed blading operating with high moisture content.

Carryover of Solids

Operation with higher temperatures and pressures also introduced problems in the boilers or steam generators. The most serious of these problems, from the viewpoint of the turbine, has arisen from carryover deposited on the working elements. This condition has been more evident in the case of superposition units. Topping turbines have relatively small parts, and even extremely small percentages of carryover when multiplied by large flows and prolonged periods of continuous operation add up so as to cause an appreciable stoppage of the steam passages. This condition results in reduced capacity of the unit and an increase in the stage pressure. Partial stoppage of the steam passages may also cause increased thrust loads on the thrust bearing.

Fig. 9—Cross-slotting of generator rotor to avoid vibration

This carryover exists in two general forms, one as soluble salts such as sodium carbonate, hydroxide, chlorides, sulphates, and the other exists as a hard silica deposit. These deposits can occur either singly or collectively.

The hard silica deposit can be most conveniently removed by mechanical means such as blasting with sand

or fly ash or by scraping. Fortunately, the hard silica deposit is the least prevalent of the two types.

The soluble salts are often removed during the starting and stopping operations. However, in some cases they must be removed by other means and the most effective method of removing the deposit is by washing with saturated steam.

A recent design innovation has been used on superposition turbines so as to minimize the effect of deposits on the blading affecting the thrust of the machine. By arranging the blading on a constant effective diameter the balance piston may be so proportioned to give an equilibrium condition regardless of the stage pressure distribution caused by blade deposits.

Overcoming Cyclic Vibrations

The development of large two-pole generators was very desirable as evidenced by the fact that the majority of all recent machines up to 50,000-kw capacity operate at 3600 rpm. Therefore, any discussion of modern steam-turbine problems would be incomplete without reference to the 3600-rpm two-pole alternator. As the size of the two-pole generators became larger, however, a new difficulty took form. This was the 120-cycle vibrations which were not apparent in the smaller sizes. These vibrations, while not of any great magnitude, proved annoying. This is particularly true when this vibration was picked up by adjacent parts such as floor plates, foundation members and other pieces of equipment.

This 120-cycle vibration originated from two sources. One was from the inequality of the moment of inertia of the generator rotor in the axis of the poles and the axis at right angles to the poles. In other words, because of the slots milled into the rotor for the rotor windings it was found that the rigidity in one plane was quite different from that in the other. A simple analogy could be had by suspending a wooden "two-by-four" on centers and slowly rotating it. The difference in the rigidity of the two planes would then become obvious. This difference in the rigidity of the generator rotor caused it to jump twice during each revolution and resulted in vibration at the journals. The effect was eliminated by cross-slotting the rotor, thereby equalizing the moment of inertia or the rigidity in the two axes. By cutting the slots at right angles to the surface of the rotor, as shown in Fig. 9, the required equalizing effect was established with a minimum removal of the rotor material.

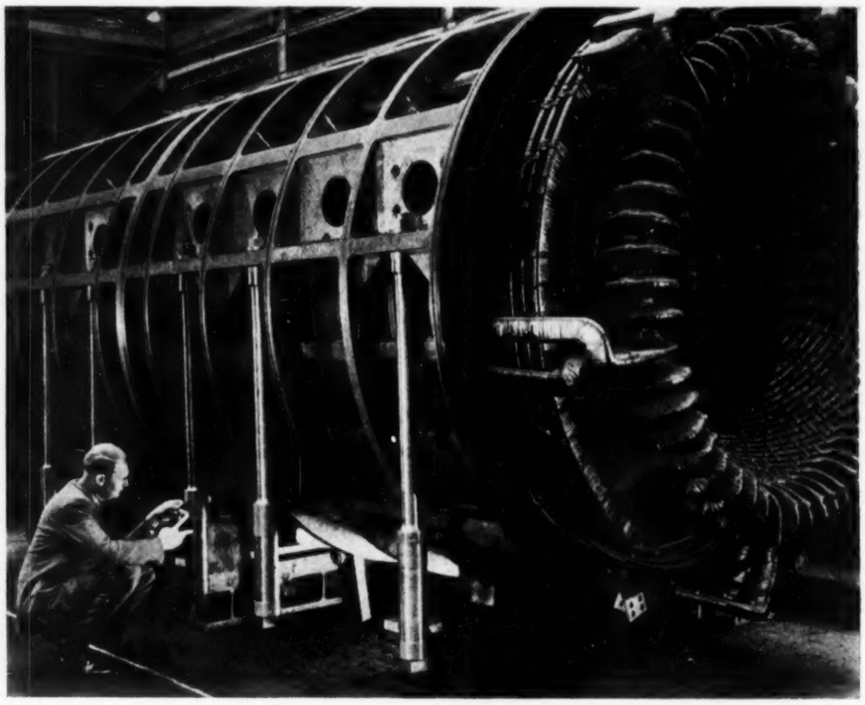

Fig. 11—Core of a 65,000-kw, 3600-rpm generator showing the core separated from the frame

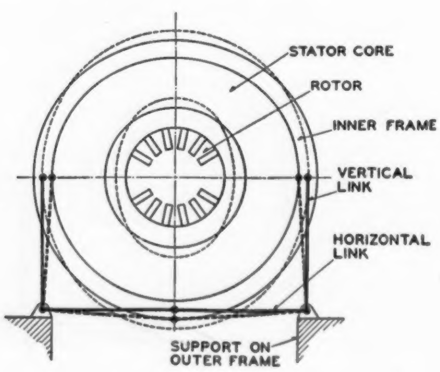

Fig. 10—Stator vibration of flexibly mounted generator

Solid lines indicate normal position without field. Dotted lines represent one point in rotation with field on

The second effect was due to distortion of the stator by the field. The field exerts a powerful force on the stator which makes it become slightly elliptical in form. This elliptical distortion revolves at the same speed as the rotor and causes a 120-cycle vibration through the generator frame and out through the foundation. Experiments have shown that while the movement of a particle near the teeth of the core is nearly circular, it became more elliptical toward the outer edge of the stator.

It has also been shown that this motion became purely radial at a certain distance beyond the outer surface of the stator core. This discovery indicated that a solution of the vibration problem could be obtained by separating the stator core from the frame. The actual physical connections between the stator core and stator frame consist of links which permit motion in a radial direction but none circumferentially or tangentially. Fig. 10 represents the stator frame and stator core schematically and Fig. 11 shows the actual core of a 65,000-kw, 3600-rpm generator.

Not all of the attention of turbine designers has been confined to the internal parts of the machine. Much improvement in appearance has resulted by employing smooth surfaces and rounded corners, as will be apparent from reference to the unit shown in Fig. 1 which represents a late design.

A.S.M.E. Spring Meeting At Houston, Texas

With "Engineering Production for Victory" as the meeting keynote, the American Society of Mechanical Engineers will hold its spring meeting at Houston, Texas, on March 23 to 25. Of special significance in this respect will be papers on the "Manufacture of Large Guns," by D. J. Martin; "Development Work of the Ordnance Laboratory at Frankford Arsenal," by John A. Bailey; "Petroleum Conservation in the War Effort," by E. L. DeGolyer; "New Responsibilities for Labor," by H. W. Acreman, J. R. Steelman and T. M. Davis; two sessions devoted to aviation; and a talk at the banquet by Brig. Gen. Earl McFarland of the Ordnance Department. A partial list of papers on power and kindred subjects follows:

"Natural Gas—Production, Distribution, and Utilization," by W. B. Poor

"Marine Boilers," by T. C. Stillman

"Effect of Valve-Seat Deflection," by Harte Cooke

"Protection of Buried Metals Against Corrosion," by Starr Thayer

"The Application of Cathodic Protection for Corrosion Prevention," by R. J. Sullivan

"A Review of Heat-Transfer Coefficients and Friction Factors for Tubular Heat Exchangers," by B. E. Short

"Condensation of Saturated Freon-12 Vapor on a Vertical Bank of Horizontal Tubes," by W. J. Wohlenberg and F. L. Young, Jr.

"Heat Transfer, Pressure Drop, and Fouling Rates of Liquids for Continuous and Noncontinuous Longitudinal Fins," by A. Y. Gunter and W. A. Shaw

"Operation and Maintenance of Air Preheaters," by Joseph Waitkus

"Construction of Water-Cooled Furnaces," by Max Kuhner

"Round-Table Discussion on Trouble Shooting on Gas and Oil Burners"—Chairman: Carl J. Eckhardt; Contributors: E. L. Dennis, R. C. Vroom, L. S. Reagan and C. L. Orr

"Automatic Control of Natural Gas Fuel Power Boilers," by Charles W. Parsons

One of the high spots of the meeting will be a visit to the Hughes Tool Company which is now engaged in the production of large guns for the Army. Preceding this trip will be the talk on the manufacture of large guns by Lieut. Col. D. J. Martin of the Ordnance Department.

Other inspection trips will include one of the shipyards, near Houston, the plant of a large sulphur-manufacturing company, one of the near-by air fields, a cement plant, and a central power station. Those interested in engineering education will have an opportunity to visit Rice Institute, the University of Texas, Texas A & M College and the University of Houston.

Headquarters for the meeting will be at the Rice Hotel which is the largest hotel in that section of the Southwest.

Research Fellowships in Coal

The University of Washington offers four fellowships in the College of Mines for Research in coal and non-metallics in cooperation with the U. S. Bureau of Mines. These fellowships will begin on July 1 and continue for 12 months with an annual allowance of $792 each. They are open to graduates of universities and technical colleges who are qualified to undertake investigations of research character. Applications will be passed upon in April.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1941 Water Tube		1940 Water Tube		1941 HRT Type		1940 HRT Type	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan....	170	968,275	62	285,042	89	123,459	51	68,639
Feb....	102	896,763	54	386,356	81	104,622	47	51,474
Mar....	133	938,605	56	438,980	86	89,324	51	58,529
April...	159	802,993	89	476,135	129	151,636	56	50,356
May...	134	850,659	101	663,721	114	154,964	75	84,094
June...	141	743,762	150	814,210	114	134,880	110	122,026
July....	184	1,184,984	111	632,373	94	121,884	89	128,784
Aug....	115	780,119	118	685,212	91	101,284	90	108,680
Sept....	121	878,996	145	944,970	61	63,385	63	65,218
Oct....	‡146	‡876,400	127	696,993	89	96,740	106	124,876
Nov....	122	887,158	155	992,046	47	45,147	78	93,593
Dec....	153	1,036,035	124	817,455	95	87,476	67	89,044
Jan.-Dec. Incl..	1,680	10,844,749	1,292	7,833,493	1,090	1,274,801	883	1,045,313

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period January to December (incl.) 1941, 113,271,000 lb per hr; in 1940 79,781,000 lb per hr.

†Mechanical Stoker Sales

	1941 Water Tube		1940 Water Tube		1941 Fire Tube		1940 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan....	77	41,975	24	10,770	94	14,036	104	14,745
Feb....	60	27,736	31	10,729	117	14,774	118	17,862
Mar....	69	31,342	35	17,460	146	21,552	76	12,717
April...	75	34,882	36	14,554	147	20,555	87	15,123
May...	90	43,971	73	30,930	144	19,267	88	11,402
June...	136	50,896	65	15,772	264	42,619	153	21,736
July....	113	50,108	86	31,199	290	40,943	189	37,227
Aug....	96	41,882	78	26,202	391	49,547	274	32,209
Sept....	83	33,663	81	39,799	335	49,559	305	41,038
Oct....	57	21,269	92	38,107	344	54,027	318	42,317
Nov....	57	25,645	67	22,107	207	27,375	182	23,380
Dec....	95	44,080	71	30,106	194	28,149	183	21,565
Jan.-Dec. Incl..	1,008	447,399	739	288,735	2,673	382,403	2,079	281,321

† Capacity over 300 lb of coal per hr.

Pulverizer Sales

	1941 Water Tube			1940 Water Tube			1941 Fire Tube			1940 Fire Tube		
	No. (N)	No. (E)	Lb Coal/Hr	No. (N)	No. (E)	Lb Coal/Hr	No. (N)	No. (E)	Lb Coal/Hr	No. (N)	No. (E)	Lb Coal/Hr
Jan....	39	—	462,990	10	—	214,250	—	1	1,000	1	—	600
Feb....	42	4	734,200	15	1	186,935	—	—	—	1	2	2,800
Mar....	‡31	3	‡739,700	17	1	317,800	—	—	—	—	—	—
April...	14	8	225,740	26	5	270,500	1	—	2,800	—	—	—
May...	54	10	777,320	30	5	447,450	—	4	7,000	—	—	—
June...	28	24	523,540	21	2	360,270	—	1	1,000	—	—	—
July....	57	7	828,640	22	2	454,400	—	1	600	—	—	—
Aug....	30	5	456,480	37	—	705,860	—	1	800	—	—	—
Sept....	38	2	468,930	37	3	1,208,960	—	—	—	1	—	2,800
Oct....	‡59	—	‡764,620	26	3	405,430	—	—	—	—	—	—
Nov....	38	4	656,630	48	—	622,480	—	—	—	—	—	—
Dec....	40	2	651,780	37	4	418,750	—	—	—	—	—	—
Jan.-Dec. Incl..	470	69	7,301,670	326	26	5,503,585	1	8	13,200	3	2	6,200

(N)—New Boilers; (E)—Existing Boilers. ‡ Revised.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Design of Piping Systems

The widespread employment of high pressures, high temperatures and increased capacities has made it necessary to make careful analyses of forces and stresses in piping, instead of relying on guides, anchors and standard expansion bends. This applies particularly to power plants, oil refineries and chemical processes.

The book under review was prepared by M. W. Kellogg Company, well-known piping fabricator, with a view toward making available for ordinary drafting-room practice a set of working charts, formulas and data that can be readily applied in designing both simple bends and systems involving a multiplicity of branches in space. To best serve this purpose an 8 × 11 page size was selected in order to accommodate the numerous diagrams and charts, and a loose-leaf ring binding is employed to permit the book to lie flat on the drafting table or desk.

Part I contains an historical review summarizing the work of various investigators and a bibliography of their contributions to literature on the subject. Part II is devoted to the derivation of formulas, to sign conventions and nomenclature. Part III contains design data, tables on the properties of pipe, elasticity and expansion curves, and stress calculations. Part IV concerns applications of the formulas and contains many charts. Special conditions are discussed and suggestions offered as to layouts.

The foregoing covers 97 pages, printed on heavy coated stock, with stiff buckram cover, in addition to which there are appended a number of pages of halftone illustrations depicting work at the Kellogg plant and laboratory. There are also a number of blank pages for the convenient assembly of personal notes and calculations.

Price $10.

Modern Pulp and Paper Making

By G. S. Witham, Sr.

The art of paper making, which originated in China in the first century of our era, became established in England in the sixteenth century, and in America in the year 1690, yet the many changes in the industry during the last twenty years have made necessary this second edition of "Modern Pulp and Paper Making" to include an up-to-date account of modern equipment and processes. Primarily, this is a book for those engaged in the industry, or for technical men desirous of knowing the salient facts concerning it. No attempt is made to treat the subject from an historical aspect, nor are chemical considerations introduced other than those which may be readily understood by the layman.

Almost every phase of present practice in the industry is covered in twenty well-written and authoritative chapters which are copiously illustrated with more than 300 halftones and line cuts. In the chapter devoted to The Power Plant the subject of steam engineering is dealt with in a general way, with special attention given to the closed loop boiler feeding system and the distribution of steam through the plant. The book comprises 705 pages and includes an 8-page index. Bound in bright blue buckram, size $6^1/_2 \times 9^1/_4$. Price $6.75.

Statistics of Electric Utilities in the United States

Issued by the Federal Power Commission

The fourth annual edition of "Statistics of Electric Utilities in the United States—Classes A and B" for the year ended December 31, 1940, presents detailed financial and operating information on 380 electric utilities and representing more than 95 per cent of the privately owned electric utility industry in the country. This 700-page publication shows for each utility: balance sheets, income and earned surplus accounts, capital stocks and bonds, electric operating revenues, customers and sales by classes of service, operating expenses, utility plant accounts, and data as to physical quantities. These are broken down to reveal all the operations and costs of the individual companies on a financial basis, to permit the comparison of virtually every characteristic of each company's operating and financial practices and results.

This compact compilation is bound in blue cloth and is sold at $2.00 per copy by the Federal Power Commission only. The publication may be referred to as FPC S-21, and all checks or money orders should be made payable to the Treasury of the United States.

Intercrystalline Cracking of Boiler Steel and Its Prevention

Bureau of Mines Bulletin 443

By W. C. Schroeder and A. A. Berk

Bulletin 443 issued by the Bureau of Mines is based largely upon an investigation of intercrystalline cracking and solubility studies that was initiated in 1933 and is still under way. The extensive nature of the work involved might be judged from the fact that over four tons of steel was used for test specimens. Whereas scale, corrosion and carryover problems have more or less been solved by the evolution of basic water-treating principles, the problem of inhibiting intercrystalline cracking or embrittlement has not yet been thoroughly understood nor adequately dealt with, and, because of the involved nature of the problem, the authors have found it necessary in several instances to limit themselves to an outline of the factors that are acting rather than isolate the quantitative effect of each. Probably the most interesting section is that dealing with protection from intercrystalline cracks.

This 85-page bulletin is illustrated with diagrams and halftones which show test specimens and apparatus and photomicrographs of cracks produced under various conditions. Price 15 cents.

Refractories—the Backbone of Industry

By John D. Ramsay

The story of refractories, which comprises Part I of this book, is reprinted from a series of ten articles which appeared in "Brick and Clay Record" which describe in an informative way the historical, technological and economic aspects of the refractory industry. Part II comprises a chapter devoted to the history, development and products of the North American Refractories Company which sponsors the book's publication. The book is illustrated and contains 116 pages, size 6 × 9, and is bound in red buckram.

American Standards for 1942

The American Standards Association announce the publication of its new list of American Standards for 1942. In view of the importance of standards and specifications, not only for every day work but to speed up production for defense, this particular list of standards should be in the hands of the engineering and purchasing departments of every manufacturing firm in the United States.

Nearly 500 American Standards are listed in a wide variety of industrial fields and in the fields of industrial and public safety. There is a separate heading for American Defense Emergency Standards—standards developed specifically for defense purposes, and for the first time all American Safety Standards are listed together in a separate section. These standards include definitions of technical terms, specifications for metals and other materials, methods of test for the finished product, dimensions, safety provisions for the use of machinery, and methods of work. They reach into every important engineering field, serving as a basis for many municipal, state and federal regulations.

This list of American Standards for 1942 will be sent free of charge to anyone writing in for it. Requests should be addressed to the American Standards Association, 29 West 39th Street New York, N. Y.

A. R. Mumford Joins C. E. C.

Albert R. Mumford, until recently assistant director of research of the Consolidated Edison Company of New York, joined the Research Department of Combustion Engineering Company on February 16. This department is under the direction of Henry Kreisinger.

A graduate of Massachusetts Institute of Technology, Class of 1918, Mr. Mumford's background in fuels, combustion and steam generation covers four years as assistant fuels engineer of the U. S.

Bureau of Mines, over fifteen years as research and design engineer with the New York Steam Corporation and from October 1938 to February 1942 as assistant director of research of the Consolidated Edison Company of New York. He has long been active in committee work of the American Society of Mechanical Engineers, the National District Heating Association, the American Society of Heating & Ventilating Engineers and the American Society of Testing Materials, and is the author of numerous technical papers.

Personals

A. W. Thorson, for a number of years with The Detroit Edison Company, and for the last two years assistant fuel service engineer for the Chesapeake & Ohio Railway Company, has been appointed to the position of assistant to the president of Carnegie Institute of Technology, Pittsburgh. In his new duties, which he assumed on February 1, Mr. Thorson will also aid Dr. H. H. Lowry director of the Coal Research Laboratory.

Word comes from England that **Dr. H. L. Guy,** for the last twenty years chief mechanical engineer of Metropolitan Vickers Electrical Company (builders of steam turbine-generators and other power equipment) has resigned after thirty years with that company. Doctor Guy has been the author of numerous technical papers before engineering groups and is well known to many engineers in this country.

Ralph J. Lundrigan has recently joined the Cochrane Corporation, Philadelphia, to supervise the handling of the new Cochrane-Becker high-pressure condensate-return system.

Captain Howard L. Vickery, U.S.N., who as a member of the Maritime Commission has had charge of the vast shipbuilding program, has recently been advanced to the rank of Rear Admiral.

W. L. Abbott, who until his retirement was Chief Operating Engineer of the Commonwealth Edison Company, was the recipient of the Washington Award for 1942 at a dinner at the Union League Club, Chicago, on February 26 under the sponsorship of the Washington Award Commission and the founder engineering societies. The citation was for "advancing the standards of the engineering profession, for service to higher education and for aiding combustion research."

Edwin H. Brown has been elected a vice president of the Allis-Chalmers Mfg. Company, in charge of engineering and development. Following graduation from the University of Nebraska in 1906, Mr. Brown entered the Allis-Chalmers training course for graduate engineers and has since served in various capacities with that company, including that of assistant manager of the steam turbine department and head of the engine and condenser section.

K. M. Irwin, assistant to the vice president in charge of engineering of the Philadelphia Electric Company, has been elected a vice president of the American Society of Mechanical Engineers to fill the unexpired term of W. H. Winterrowd, deceased.

Obituaries

Percy Nicholls, supervising engineer of the Fuels Section, U. S. Bureau of Mines, died at Pittsburgh on February 12 following an operation. He was in his 72nd year. Born in London, Mr. Nicholls was educated at Leeds University and came to this country in 1897. From then until 1914 he was variously employed by the Westinghouse Electric & Mfg. Company, the Western Electric Company and the General Electric Company. In 1915 he became director of planning and research of the Franklin Manufacturing Company; from 1922 to 1925 was on the staff of the A.S.H.V.E. Research Laboratory and in the latter year accepted an appointment as supervising engineer of the Fuels Section, U. S. Bureau of Mines. He was a member of the A.S.M.E., the A.S.H.V.E. and the Physical Society of Pittsburgh and was the author of more than fifty papers on technical subjects and research.

Reginald Pelham Bolton, consulting engineer, died at his home in New York City on February 18 after a brief illness. He was in his 86th year, and had been active in engineering work until a short time before his death. Born in England, Mr. Bolton came to this country when 23 years old and shortly thereafter engaged in

consulting work. Until 1892 he spent much of his time on foreign engineering projects and later became connected with the Department of Water Supply for New York. Among the installations with which he was associated in a consulting capacity were the plants of R. H. Macy & Co. and the Grand Central Terminal in New York. He was a member of many engineering organizations, including the A.S.M.E., the A.S.C.E. and the A.S.H.V.E., being a past president of the last-named society.

Warren Davey, research engineer of the Colgate-Palmolive-Peet Company, died in Jersey City on February 24 at the age of 65. A graduate of Stevens Institute of Technology with the Class of 1897, he joined the foregoing company in 1902 as a mechanical engineer in the research department.

Charles Clarage, president of the Clarage Fan Company, died of a heart attack at his home in Kalamazoo, Mich., on February 6. He was 81 years old and had founded the Clarage Fan Company in 1915, although for some years previous he had been building fans and blowers in the foundry and machine shops which he and his brothers had inherited from their father. He was active in the affairs of his company until his death.

H. H. Clemens, President of the Erie City Iron Works, died suddenly of a heart attack on January 27 in Dallas, Texas. He had been a former president of the American Engine and Boiler Manufacturers Association, was a director of the Hays Manufacturing Company and also a member of the Board of Directors of the American Cyanamid Company.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Condensate Return System

The Cochrane Corporation has announced a 4-page bulletin (Publ. 3025) covering the new Cochrane-Becker high-pressure condensate return system.

A typical installation is described in detail with a four-color illustration showing steam, condensate and makeup lines. A similar drawing illustrates the operation of the jet-loop principle on which the system operates.

Deaerator Control System

The Brown Instrument Company has just issued a new 6-page bulletin (No. 29-34) describing its remote "new-matic" deaerator control system. Included are descriptions of the principles involved and application data, together with schematic diagrams showing how the system is hooked up for boiler operation.

Fly Ash Elimination

The Western Precipitation Corporation has issued an attractive two-color 24-page bulletin which describes the application of its VF Multiclone to the problem of eliminating fly ash. Collection efficiency charts are given for this type of equipment and also charts to determine the number of multiclone tubes required for gas volumes up to 240,000 cfm under different conditions of temperature and draft loss. Five pages are devoted to dimension sheets and several cutaway views and diagrams illustrate the operation of the equipment. Installation views are also given together with pictures of testing equipment and views of the company's research laboratories.

Induction Motors

A new 22-page bulletin issued by the General Electric Company (GES-2536) describes pictorially the application of induction motors to power station auxiliaries. The text, backed up by both application and product photographs, tells which motor to select for such power station applications as induced- and forced-draft fans, boiler-feed pump drives, condensate and hot-well pumps, circulating pumps, service-water, deaerator, and evaporator pumps, coal pulverizers, and other general applications. The construction features of the various motors are also described and depicted. The bulletin closes with a tabulation covering the motor characteristics of typical applications for power station auxiliaries.

Insulation and Refractories

The 1942 edition of the Johns-Manville Industrial Products catalog is now available. This 52-page booklet is profusely illustrated with installation views and many construction diagrams and contains a wealth of information and recommendations from 400 F below zero to 2500 F above. Complete data are also given on J-M refractory products and castables, and special products for flooring, roofing and siding. Transite walls, transite vent and pressure pipe, electrical materials, friction materials, packings and gaskets are also included.

Recording and Controlling Instruments

A new 36-page catalog (No. 1101 G) has just been received from the C. J. Tagliabue Manufacturing Company. This booklet is profusely illustrated with instrument, detail and installation views of various single- and multiple-point indicating, recording and control instruments which feature the Tag "celectray" photo-electric device. Specifications are also given for each instrument described.

Remote Speed Indicator

The Reeves Pulley Company has issued a 4-page illustrated folder (G-427) describing a recently developed electric remote speed indicator for use with Reeves variable-speed control equipment.

Signaling Conductivity Controller

An illustrated 8-page bulletin (N-95-163-1) issued by The Leeds & Northrup Company describes a new instrument for steam plants where indicating and recording instruments are not required which automatically tests the purity of condensate, and indicates by signal lights whether condensate is above a specified minimum purity and safe to use again, or whether it should be diverted to waste.

Stop Valves

The Edward Valve & Mfg. Company has issued a 4-page illustrated folder (catalog No. 12-G5) describing integral-seat globe stop valves for pressures up to 1500 lb at 950 F. These valves are available in $^1/_2$-in. to 2-in. sizes in socket welding, flanged or screwed ends.

Turbine Blowers

The L. J. Wing Mfg. Company has issued a 16-page bulletin (T-98) which illustrates and describes 27 typical turbine-blower installations for forced draft on oil- and stoker-fired boilers, as well as for pulverized coal, gas, wood and hand-fired operations. Details of turbine construction, lubrication, bearings and other features of the turbine-blower assembly are also presented, accompanied by numerous drawings and diagrams.

Welding Instruction

A new 88-page book, "Training Oxy-Acetylene Welding and Cutting Operators—Instructors' Outlines," has been prepared and published by the International Acetylene Association. The book presents in three chapters the essential information that should be given in a course for the training of (1) a general welding operator, an aircraft-welding operator and a pipe-welding operator, (2) various types of cutting operators and (3) inspectors. Paper bound copies are obtainable at 25 cents each, and cloth bound copies at 75 cents.

BOOKS

1—Steam Turbine Principles and Practice

BY TERRELL CROFT, REVISED BY S. A. TUCKER

298 Pages Price $3.00

This book was revised to include the latest developments in turbine design and application. It provides the plant superintendent, the operating engineer and the manager with the information necessary to insure the successful selection and economic operation of steam turbines.

2—Boiler House and Power Station Chemistry

BY WILFRED FRANCIS

203 Pages Price $4.50

This book provides chemists, boiler-house operators and students with information on the fundamental considerations involved in fuel burning and the generation of steam and electricity.

3—Training Procedure

BY FRANK CUSHMAN

225 Pages Price $2.00

This book discusses the problems encountered in planning, organizing, operating and maintaining effective training programs in industrial, business and public service organizations.

4—Applied Chemistry for Engineers

BY ERIC S. GYNGELL

328 Pages Price $4.00

This book deals with the chemistry of materials and processes used by the engineer. Fuels and combustion are treated fully, with chapters devoted to wood, peat and lignite, formation and classification of coal, coal analyses and constitution, gaseous fuels, liquid fuels, combustion and the like. Metallic corrosion is given the next fullest treatment and there are chapters on direct attack, indirect attack, anodic and atmospheric corrosion, inhibitors and protective films. Other sections of the book are devoted to paints and varnishes, water treatment and sewage disposal, cements and lubrication.

5—Stoker Handbook

BY H. D. AIRESMAN

200 Pages Price $3.00

Written as a practical text for those who design, sell, install and operate small industrial or domestic stokers, the book presents the fundamentals of combustion and heating, discusses different fuels and their characteristics, shows how to conduct gas analyses and make tests, how to estimate coal consumption, to determine the size of stoker required, and gives helpful data on the operation and care of stokers.

6—Gas and Oil Engines

BY P. S. CALDWELL

125 Pages Price $1.50

This pocket-size volume is intended as a handbook on the running and maintenance of gas and oil engines for the practical man and the student. It covers engine details, governing, cooling, lubrication, starting and stopping, care, engine troubles, methods of testing and typical test results.

7—Boiler Feedwater Treatment

BY F. J. MATTHEWS

319 Pages Price $5.00

The text of this book is divided into five parts covering natural water supplies, scale formation, corrosion, foaming and priming, and analysis and routine testing. It is intended primarily as a guide for the "small average" steam plant operator but the text contains rather comprehensive studies.

8—Boiler Operators Guide

BY HARRY M. SPRING, JR.

353 Pages Price $3.00

This is intended as a practical manual of steam boiler operation and maintenance for operating engineers, boiler inspectors and those preparing for license examinations. The designs of typical boilers are included as well as methods of installation, operation and maintenance.

9—Steam Boilers

BY TERRELL CROFT, REVISED BY R. B. PURDY

417 Pages Price $4.00

The text of this book, first published about 15 or 16 years ago, has been brought up to date. It covers the various classes of steam boilers, firing equipment and boiler accessories, including chimneys and feedwater treatment.

10—Pumps

BY FRANK A. KRISTAL AND F. A. ANNETT

339 Pages Price $3.50

The authors make available herein a comprehensive presentation on types and designs of pumps and the applications for which they are suited. This book was compiled essentially for the user as an aid in the selection of pumps.

11—Practical Mathematics

BY G. M. HOBBS, J. MCKINNEY AND J. R. DALZELL

599 pages Price $2.40

This, the second edition, is devoted to the phases of mathematics most widely used in trade and in applied branches of engineering. It is intended for beginners and for those who wish to brush up on long-forgotten fundamentals with a minimum of time and effort.

The book covers addition, subtraction, multiplication and division as well as fractions, decimals, percentage, factoring, powers, roots, ratio and proportion, equations, formulas, graphs and logarithms. Illustrative problems, which are worked out and explained in detail, are practical ones such as would be encountered in the different branches of engineering. By the study of such problems the student learns mathematics as well as its application to the fields of business.

Supplementing the mathematical considerations there are many tables including weights and measures and numerous suggested problems and examination questions with the answers.

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